OZON[E]

Dr.

CORNELIUS

FOX

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OZONE AND ANTOZONE

WHEN WHERE WHY HOW	IS OZONE OBSERVED IN THE ATMOSPHERE?

Rev. Edward Hughes. D.D.

County Wexford.

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OZONE AND ANTOZONE

WHEN WHERE WHY HOW	IS OZONE OBSERVED IN THE	ATMOSPHERE?

OZONE AND ANTOZONE

THEIR HISTORY AND NATURE

WHEN
WHERE
WHY
HOW
} IS OZONE OBSERVED IN THE ATMOSPHERE?

ILLUSTRATED

WITH

WOOD ENGRAVINGS, LITHOGRAPHS, AND CHROMO-LITHOGRAPHS

BY

CORNELIUS B. FOX, M.D. EDIN.

MEMBER OF THE ROYAL COLLEGE OF PHYSICIANS, LONDON;

FELLOW OF THE BRITISH METEOROLOGICAL SOCIETY; FELLOW OF THE OBSTETRICAL SOCIETY;

MEMBER OF THE SCOTTISH METEOROLOGICAL SOCIETY, ETC.

"Ye who amid this feverish world would wear
A body free from pain, of cares a mind,
Fly the rank city, shun its turbid air;
Breathe not the chaos of eternal smoke
And volatile corruption."—*Armstrong*.

LONDON

J. & A. CHURCHILL, NEW BURLINGTON STREET

1873

TO THE MEMORY

OF THE

GREAT AND ILLUSTRIOUS FATHER

OF OZONOMETRY,

C. F. SCHÖNBEIN,

LATE PROFESSOR OF CHEMISTRY AT BASLE,

WHOSE BRILLIANT SCIENTIFIC RESEARCHES DESERVE

THE GRATITUDE OF THE WORLD,

THE FOLLOWING PAGES ARE

DEDICATED.

PREFACE.

THE importance of the subject of Ozone is so great, and the amount which has been written respecting it is so large, that, although a collection of statements regarding its nature and properties is very desirable, such an aggregation would form a most indigestible mass of contradictory evidence which would meet with few readers.

A succinct account of all the results that have been arrived at is required. But the difficulties of this undertaking are great, in consequence of the dispersion of the majority of the papers concerning Ozone through the Journals, Reviews, and Proceedings of the Scientific Societies, of England, France, Germany, Italy, and America.

Ozone is a body, then, which has been the subject of vast erudition. Great are the number and variety of publications in which we are continually encountering notices respecting it, from guide-books and newspapers up to Transactions of Philosophical Societies, both English and Foreign. It seems desirable to sift the chaff from the wheat, to summarize our knowledge respecting it, and concentrate the most important facts which have been elicited by those who have laboured at the solution of the mysteries with which it has been enveloped. A basis will thereby be formed for all future investigations, and, instead of running shafts into ground which has been explored and proved to be unfruitful, we shall have an opportunity of becoming acquainted with all that has

been ascertained of importance respecting strata which present a more encouraging prospect.

Antozone, although regarded by many chemists as a myth, has been, with a few exceptions, considered throughout Germany to be a distinct allotropic modification of Oxygen. The majority of scientific observers in this country appear to be strangers to the researches that have been made in the Fatherland concerning it. We cannot wonder at this fact, as the greater portion of them are almost inaccessible. The occasional existence of a state of the atmosphere antithetical in its nature to that of Ozone, has been recognized by several of the meteorologists of Great Britain, but we at present know little about it.

My object in the following pages is threefold:—

1. To give a digest of the most important facts connected with Ozone and Antozone;

2. To point out the circumstances and the manner in which, the localities where, and the reason why, Ozone is observed in the atmosphere; and,

3. To give the results of my own investigations concerning these bodies.

I cannot conclude these prefatory observations without thanking the many distinguished men who have aided me in the prosecution of this work for their extreme courtesy and kindness.

Scarborough, 1872.

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INTRODUCTORY REMARKS.

To the Philosopher, the Physician, the Meteorologist, and the Chemist, there is perhaps no subject more attractive than that of Ozone. Whether the scientific man studies it in relation to its supposed functions in the atmosphere, or to its presumed connection with epidemics; whether he dives into the mysteries of its origin, or speculates on its relationship with Oxygen: he finds it to be an extremely interesting body, concerning which little is in reality known, and an immense amount has been written. The results of all the labour that has been bestowed on the observation of atmospheric Ozone, and on investigations respecting Antozone, have led to the somewhat depressing conclusion, that the greater part of our knowledge as to the former principle does not rest on a reliable basis, and that the latter is not the antithetical form of Oxygen which it has been represented to be by Schönbein and his disciples. Atmospheric Ozone has, as I shall show in the following pages, never yet been correctly estimated. This is a somewhat startling statement: its truth, however, can easily be demonstrated.

It requires but little acquaintance with the subject to readily understand, that the accurate determination of the amount of Ozone present in pure air is a foundation stone, on which all observations as to its action on animals and plants in a state of health and disease must be built. Real progress in knowledge cannot possibly be made by

the propagation of wild assumptions and speculative guesses, but is generally the result of piercing and intense thought, supported by observation and experiment.

Without further introduction, I will give, in the first place, a brief sketch of the history of Ozone and Antozone, and then consider the replies which modern science affords to the inquiries, which will arise in the minds of all who require information respecting these bodies.

HISTORY OF OZONE AND ANTOZONE.

TRAVELLERS in various countries have often in their descriptions of storms referred to the production during these periods of electrical disturbance of a peculiar odour similar to that of Phosphorus or Sulphur. For example, Wafer states that, in crossing the Isthmus of Darien, the thunderstorms were accompanied by "a sulphurous odour powerful enough to take away the breath." Similar observations were made on board an English ship called the "Montague," and a packet named the "New York," when these vessels were struck by lightning in the years 1749 and 1827 respectively.

Odour accompanying thunder storms.

The same smell appears to have been observed by the Ancients in connection with flashes of globular lightning, which the ignorant in all past times have designated "thunderbolts." Homer refers, both in the *Odyssey* and in the *Iliad*, to the odour of thunderbolts.[1] Jupiter is said to strike a ship with a thunderbolt, *εν δε ϑεειου πληντο*, "quite full of sulphurous odour" (*Odyssey*, B. xii. v. 417, and xiv. v. 307). Jupiter hurls a bolt, "with the flame of the burning sulphur," into the ground before Diomede's chariot (*Iliad*, viii. 135). Ajax hurls a rock at Hector, who falls "like a mountain oak struck by lightning, which lies uprooted, and from which the fearful smell (*οδμη*) of smoking sulphur rises" (*Iliad*, xiv. 415).

This odour has been said to accompany displays of the Aurora Borealis and Australis; but this statement is of doubtful veracity.

The *populus vulgaris* has for many centuries believed implicitly that flashes of lightning are followed by the

[1] Mohr, in Pogg. *Ann.*, xci. 625.

diffusion in the air of an odour resembling that of onions, Sulphur, or gunpowder. Cautious scientific men, who refuse to place very much reliance on the evidence of the senses, have doubted the statements which have been circulated, averring, that it is very easy to connect the blue tint of lurid lightning with the appearance of burning Sulphur, and then imagine its odour.

There is every reason to believe, however, that a peculiar odour is sometimes perceptible during thunderstorms, and that this odour is identical with that of Ozone.

The following incident is narrated by Schönbein:—[1] M. Buchwalder, a Swiss engineer, was one day on the summit of the Senlis, near Appenzel, with his servant. They were reclining in a little tent erected in the snow, when they were suddenly enveloped in a thunderstorm. The servant was killed on the spot, and, immediately after, the tent was filled with a very powerful and remarkable odour. One day when M. Schönbein was experimenting with Ozone, his laboratory being filled with its odour, he received a visit from M. Buchwalder, who recognised the odour as precisely similar to that which he had perceived in his tent on the mountain.

Discovery of Ozone.

The impetus given to the study of Chemistry by the discovery of Oxygen in 1774 was experienced throughout Europe. Large numbers of experiments on the "vital air" of Priestley were made in various countries. At the close of the century, about the year 1785, Van Marum of Holland, having passed electric sparks through this gas, observed that it had acquired a peculiar smell, and the power of acting directly on Mercury.

Cavallo, at the commencement of the present century, noticed that this "electrified air" had a purifying effect on animal and vegetable matter, when in a state of decomposition, and employed it as a disinfecting application to fœtid ulcers.

[1] *L'Union Médicale*, p. 82. 1853.

Van Marum called this smell the "electrical odour," whilst Cavallo spoke of this condition of the air as the "aura electrica."

In 1826, Dr. John Davy recognised[1] the existence of this principle in the atmosphere, and published a formula for the preparation of chemical tests to be used in its detection, resembling that afterwards adopted by Schönbein.

In 1839, M. Schönbein, the Professor of Chemistry at Basle, and the inventor of gun-cotton, whilst engaged in some experiments on the decomposition of water by voltaic electricity, was astonished at the development of a peculiar odour, similar to that emitted during the working of an electrical machine. He made a number of experiments with the view of discovering the cause of this phenomenon, the results of which were published in the *Memoirs of the Academy of Munich.*

The odour emitted by the electrical machine when in action had been explained by assuming, that the sensation is due solely to a peculiar action of the electricity on the olfactory organs, and not to the presence of a material substance.

Schönbein showed that it was due to the existence of a body possessing, like Oxygen, the property of entering most readily into chemical combination. In the following year a letter was published by him, entitled "Recherches sur la Nature de l'odeur qui se manifeste dans certaines actions chimiques," which appeared in *Compt. Rend. de l'Acad. des Sciences*, April 27, 1840. This communication was soon followed by others, which found their way into most of the chemical journals of Europe. Schönbein in this manner soon drew the attention of the scientific world to the remarkable properties of this rediscovered body which he named Ozone (ὄζω, to emit an odour).

He showed that this odorous gas was contained in the Oxygen evolved at the positive pole during the decom-

[1] *Lectures on Agricultural Chemistry.*

position of water by the voltaic pile. De la Rive imagined that the remarkable odour was due to the action on the organs of smell of very finely divided metallic dust of Platinum or of Gold, which was separated from the conductors by the electric current and converted into oxides of the metals. Schönbein proved this explanation to be untenable, and discovered that this same gas may be produced, without the aid of electricity, by the slow oxidation of Phosphorus in moist air or Oxygen. He, in addition, recognised the identity of the smell with that accompanying a flash of lightning during a storm on the Jura. After devoting many years to the study of this body, he expressed his belief that Oxygen may be split up or transformed—a half into Ozone, or Oxygen in a negatively polar state, and a half into a body named by him Antozone, or Oxygen in a positively polar condition.

Discovery of Antozone.

Much labour has been expended in the determination of the nature of Antozone, concerning which there is now but little doubt.

Names of labourers in this field.

During the thirty years which have elapsed since the famous researches of Schönbein, Ozone has been studied by some of the most illustrious men of the century; for example—

Berzelius,	Williamson,
De la Rive,	Baumert,
Marignac,	Andrews,
Becquerel,	Tait,
Fremy,	Soret,
Erdmann,	etc.

To Faraday, Odling, Meissner, Houzeau, Von Babo, Fischer, Nasse and Engler, Scoutetten, Moffat, Lowe, Boehm, Gorup-Besanez, Weltzien, Bertazzi, Daubeny, Boettger, Schiefferdecker, Langlois, Pless and Pierre, Zenger, Allnatt, Bineau, Angus Smith, C. Kosmann, Wolf, Carey Lea, Wetherill, Poey, Seitz, Rogers, Boeckel, Osann, Day, Reslhuber, Bérigny, Smyth, A. Mitchell, and

many others, is the credit due of having either made some contributions to our knowledge regarding Ozone and Antozone, or of having brought the discoveries of others before the notice of their fellow-countrymen.

Such, then, is a brief resumé of the mode in which the light of knowledge concerning Ozone and Antozone has dawned on the minds of men, and a short list of the many labourers in this field. One hypothesis after another has arisen and fallen. Notwithstanding all obstacles, however, to the progress of truth, we are advancing steadily towards full daylight, and are apparently on the eve of great and important discoveries respecting these interesting and important substances.

WHAT IS OZONE?

FOR more than a quarter of a century have chemists been endeavouring to give a decisive answer to this query. That many differences of opinion have prevailed respecting its nature is exhibited by its possession of many synonyms.

Various names.

It has been named "electricized Oxygen," "allotropic Oxygen," "nascent Oxygen," "active Oxygen," "erregter sauerstoff" = excited Oxygen.

Different views regarding its nature.

Omitting all reference to the crude theories held by the earliest investigators, we find that Schönbein at first[1] supposed Ozone to be a body, which, in union with Hydrogen, constituted Nitrogen. The investigations of Osann led him to regard Ozone as a compound of Nitrogen.[2]

In 1845, Marignac and De la Rive showed that the Ozone odour was produced by the decomposition of water free from Nitrogen, and that Ozone contains nothing but Oxygen, of which they considered it to be an allotropic modification.[3]

Berzelius also expressed the opinion that Ozone is only Oxygen in a peculiar state.[4]

Schönbein, in 1847, disputed the truth of this assertion, contending that Ozone is a higher oxide (HO_3) than Thenard's Peroxide of Hydrogen (HO_2). He afterwards asserted that the formula of Ozone is HO_2.

Williamson, relying on a long series of researches, supported this last view of the Professor of Basle. Errors

[1] Pogg. *Ann.* l. 616, 1840; and *Archives de l'Electricité*, t. iv. p. 333.

[2] *Annalen der Chemie und Physik*, t. lxxv. p. 386.

[3] "Sur la Production et la Nature de l'Ozone:" *Comp. Rend.* vol. xx. pp. 808 and 1291.

[4] Pogg. *Annal.* t. lxvii. p. 142.

were, however, subsequently shown to have crept into his experiments.

In 1852, Becquerel and Fremy[1] not only confirmed the observations of Marignac and De la Rive, but demonstrated that pure Oxygen may be entirely converted into Ozone by the prolonged action of electricity, and the absorption of the Ozone, as fast as it is produced, by Mercury or Iodide of Potassium.

Baumert held[2] that the odorous gas evolved in the electrolysis of water is different from that obtained by passing sparks of electricity through air or Oxygen. The conclusion then arrived at was, that there existed two kinds of Ozone: the one, obtained by electrolytic action, being a Trioxide or a Binoxide of Hydrogen; and the other, procured by passing electric sparks through Oxygen, or by the action of Phosphorus on moist air, being allotropic Oxygen.

The experiments of Andrews[3] in 1856, which have been verified by Soret and Von Babo,[4] demonstrated that Ozone is identical in its nature, by whatever process it is formed. The theory of Williamson and others, based on the allegation that water is always formed during the destruction of Ozone, and which consequently assumed the absolute necessity for the presence of Hydrogen in the production of Ozone, was proved by Andrews and Tait to be untenable. They converted Oxygen, from which all possible sources of Hydrogen were entirely excluded, into Ozone, by means of the electric spark, to the extent of one part in twelve. They also showed that in this change there is a condensation of the Oxygen and a reduction of its volume. After the prosecution of further researches, Baumert acceded to the opinion of Marignac, De la Rive, Berzelius, Erdmann, Marchand, Fremy, and Becquerel, that Ozone is an allotropic condition of Oxygen.

[1] "Recherches électro-chimiques sur les propriétés des corps électrisés," in *Annales de Chimie et de Physique*, 3e serie, tome xxxv. p. 62.

[2] Pogg. *Annal.* lxxxix. 38.

[3] *Philosoph. Trans.* 1855-1860.

[4] Liebig's *Annal. Suppl.* bd. ii. 266.

In 1858, Schönbein discovered that, if to diluted Peroxide of Hydrogen a few drops of a solution of Acetate of Lead be added, Peroxide of Lead is formed. When the Peroxide of Lead thus produced remains in contact with the Peroxide of Hydrogen, both are reduced, the result being Water, Protoxide of Lead, and Oxygen. From this reaction, he assumed that the Oxygen in the Peroxides of Hydrogen and Lead exists in an opposite condition of polarity, $HO\overset{+}{O}$ and $PbO\overline{O}$, and that, by the union of these molecules of Oxygen, the ordinary inactive Oxygen results. He found also that, if Peroxide of Hydrogen be added to a solution of Permanganate of Potash, both the Peroxides are deoxidized, and that this change was attended by a large escape of ordinary oxygen;—an experiment which he explained, by assuming that the excess of Oxygen in one of the Peroxides is in an opposite condition of polarity to that in the other, and that they combine to neutralise each other. He was hence led to believe in the existence of two opposite and antagonistic forms of Oxygen, a negative and a positive form, named respectively Ozone and Antozone, which, when united, produce neutral Oxygen. Oxygen being represented as $\oplus\ominus$, Ozone, according to this view, is $\ominus\oplus\ominus$, and Antozone is $\oplus\ominus\oplus$. Clausius and De la Rive also imagined a similar molecular condition for Oxygen. Scoutetten,[1] who first published a work on Ozone, thinks that it is Oxygen positively electrified. Schönbein, moreover, considered that these bodies are produced whenever Oxygen enters into combination with oxidizable matters, organic or inorganic, in the presence of moisture, and that the molecule of Oxygen becomes in such cases chemically polarized. He called those bodies containing Oxygen in a negatively

Schönbein's views.

[1] "L'Ozone ou Recherches Chimiques, Météorologiques, Physiologiques et Médicales sur l'Oxygène Electrisé :" Paris, 1856.

active condition ($\overline{O}$) Ozonides, and designates those possessing positively active Oxygen Antozonides ($\overset{+}{O}$).

	Ozonides.			Antozonides.	
Evolve Chlorine from Hydrochloric acid and the Chlorides. Render Guaiacum paper blue.	Acid Permanganic	Electro-negative to the Antozonides.	Do not evolve Chlorine from Hydrochloric acid. Do not colour a Guaiacum test.	Peroxide of Hydrogen	Electro-positive to the Ozonides.
	,, Chromic			,, Barium	
	Peroxide of Manganese			,, Potassium	
	,, Silver			,, Sodium	
	,, Lead			,, Strontium	
	,, Cobalt			,, Calcium	
	,, Nickel				
	,, Bismuth				
	,, Chromium				
	,, Iron				

This hypothesis has been mainly based on the circumstance that, when an Ozonide was mixed under suitable conditions with an Antozonide, ordinary Oxygen was evolved; the Ozone of the former, according to Schönbein, combining with the Antozone of the latter.

Sir B. Brodie made a communication[1] to the Royal Society in 1861, in which he showed that the differences in the behaviour of the various classes of Peroxides above referred to are not fundamental and characteristic, and that they can be explained more satisfactorily and simply by reference to the ordinary laws of chemical change. This chemist is of opinion that Oxygen, as well as other elements, may probably exist in opposite polar states in different compounds, but he denies that there is any necessity for the explanation of any known facts to maintain, as Schönbein does, the existence of two kinds of Oxygen essentially distinct and capable of isolation.[2]

Brodie's researches.

The supposed difference in the action of an Ozonide and an Antozonide on Hydrochloric acid cannot be admitted. Brodie and Weltzien[3] have shown that the Peroxide of Barium (an Antozonide) will, when treated with concentrated Hydrochloric acid under certain conditions, evolve Chlorine; whilst Nasse and Engler have

[1] "Note on the Oxidation and Disoxidation effected by the Peroxide of Hydrogen," vol. xi. No. 46.
[2] See also *Philosoph. Trans.*, 1863, p. 837.
[3] *Annalen der Chemie und Pharmacie*, cxxxviii. 163.

further observed, that concentrated Oxygenated Water (another Antozonide) will, under the influence of concentrated Hydrochloric acid, set this gas free.[1]

Andrews' and Tait's researches.

In 1860, a paper of an extremely important character, "On the Volumetric Relations of Ozone," was published in the *Philosophical Transactions* by Andrews and Tait. A very lucid description of these researches may be found also in the *Medical Times and Gazette* of October 5, 1867, and a good digest of them from the pen of Professor Heaton.[2] As the original essay of the above-mentioned distinguished chemists is now almost unobtainable, it will be necessary to cull from these two sources.

"These observers, confirming the previously known fact, that only a small proportion, in extreme cases only $\frac{1}{12}$th, of the Oxygen can by the electric discharge be converted into Ozone, found that a constant and considerable diminution of volume accompanied the change. 100 volumes of Oxygen, when subjected to the silent discharge, which is found to be the most operative, may contract to about 92 volumes, but never to much less than this. Hence Ozone must be denser than Oxygen,—a fact which alone would suffice to refute Schönbein's view. But another most startling circumstance was next observed. Mercury, or some other oxidizable substance, was introduced into the ozonised Oxygen, and the Ozone entirely absorbed. Strange to say, the Oxygen which remained behind was found to have precisely the same volume as it had before the removal of the ozone. If 92 volumes of ozonised Oxygen were so treated, 92 volumes of Oxygen, free from Ozone, would in all cases remain behind, so that the density of Ozone appeared to be absolutely infinite. On the other hand, if the ozonised Oxygen were heated, the original 100 volumes would be obtained, because

Ozone is much denser than Oxygen.

[1] A criticism showing the improbability of Schönbein's theory is to be found in the *Journal für prakt, Chemie*, 86, p. 30—*Chemisches Centralblatt*, No. 44, 1862.

[2] *The Student*, February 1868.

Ozone is destroyed by heat. Andrews and Tait did not attempt to account for this extraordinary fact; but soon afterwards Dr. Odling suggested an explanation, which has recently been confirmed in a most striking manner by an experiment of Soret."[1]

To render Dr. Odling's theory of Ozone intelligible, a knowledge of the accepted theoretical conception amongst chemists of the nature of gases is necessary.

The prevalent belief as to the nature of gases.

Every gas consists of excessively minute, indivisible particles, called *atoms*, which, by their aggregation, form *molecules*. The molecules of all gases, whether elementary or compound, have an equal size, and, at the same temperature and pressure, a given volume contains always the same number of them. The molecules of the various elements contain single or many atoms. The molecules of compound gases are composed of two or more different kinds of atoms. The formulæ which chemists employ are now always constructed so as to denote one molecule of each element or compound, each symbol denoting one atom—*e.g.*, Hg, H_2 represent single molecules containing respectively one and two atoms of Mercurial vapour and Hydrogen. In the same way HCl, H_2O, H_3N, are the formulæ which stand for single molecules of Hydrochloric acid, Aqueous Vapour, and Ammonia; the first compound containing one atom, the second two, and the third three atoms, to form each molecule.

Dr. Odling's Theory.

The formula of Oxygen being now considered by chemists to be O_2, Dr. Odling thinks that the molecule of Ozone contains three atoms of Oxygen, and that its formation simply means the condensation of Oxygen into two-thirds of its former volume. This theory would represent the formula of Ozone as O_3 or O_2O, and would attribute its oxidizing power to the ease with which each molecule loses its third atom of Oxygen. According to this view, Andrews' and Tait's results become easily comprehensible. 100 cubic inches of Oxygen yield 92 cubic inches of

[1] *Compt. Rend.* Nov. 27, 1865.

ozonised Oxygen, because 8 cubic inches coalesce with 16 cubic inches to form 16 cubic inches of Ozone. The change may be thus represented:—

$$4O + 8O_2 = 8O_3.$$

If the gas is heated the original volume is restored, because the 16 cubic inches of Ozone (O_3) yield 24 cubic inches of Oxygen (O_2). When the Ozone is absorbed by Mercury, it is really only the third atom which combines with the Mercury; the 16 cubic inches of Ozone, therefore, become 16 cubic inches of Oxygen, and the volume remains unaltered, *e.g.*—

$$\underset{\text{16 volumes.}}{8O_3} + 8Hg = \underset{\text{16 volumes.}}{8O_2} + 8HgO.$$

The same view would account for the mutual reduction which Ozone and Peroxide of Hydrogen exercise upon one another, and, in fact, for all the known reactions of Ozone.

$$\underset{\text{Ozone.}}{O_3} + \underset{\text{Peroxide of Hydrogen.}}{H_2O_2} = \underset{\text{Oxygen.}}{2O_2} + \underset{\text{Water.}}{H_2O}.$$

This beautiful hypothesis, however, must have remained a mere hypothesis, but for the remarkable experimental verification which it has received from the hands of M. Soret. He has discovered that, whereas most substances only remove the third atom of Oxygen from Ozone, Oil of Turpentine is capable of absorbing *the whole molecule*. If the 92 cubic inches of ozonised Oxygen are treated with Oil of Turpentine instead of with Mercury, a white cloud is produced, and the residual Oxygen is found to occupy a volume of only 76 cubic inches. The only possible explanation here is, that the 92 cubic inches consisted of 16 of Ozone (O_3) and 76 of unaltered Oxygen (O_2), and that the former was seized upon entire, and removed in the solid form by the Oil of Turpentine.

M. Soret's discovery.

MM. A. and P. Thenard's investigations.

MM. A. and P. Thenard have been led to doubt,[1] in their recent comparative experiments as to the action of Ozone on Indigotic Sulphate and on Arsenious Acid, whether Ozone is really a triple atom molecule. They found that this body, although acting on the latter substance in accordance with the law of equivalents, decolorizes three times as much Indigo as this chemical law would lead one to suppose, and that the reaction takes place in two well-marked periods. Two-thirds of the Indigo are decolorized in the first of these periods almost instantaneously, and one-third in the second period after the lapse of several hours. These chemists ascribe this "*action continuatrice*" to Peroxide of Hydrogen formed by the Ozone, and are inclined to think that Ozone may be simply Oxygen in which is condensed a powerful selective force.

[1] "Mémoire sur l'action comparée de l'Ozone sur le sulfate d'indigo et l'acide arsénieux"—*Compt. Rend.*, August 19, 1872.

The two rival theories.

Of the two rival theories as to the nature of Ozone, the latter one—namely, that Ozone consists of OOO, and is allotropic or condensed Oxygen, or Oxygen *plus* force—is held by the majority of savants; whilst the former theory propounded by Schönbein respecting the three distinct states of Oxygen is supported by a minority, although quite inconsistent with the facts concerning the density of Ozone which have been recently ascertained.

Professor Tindall thinks that Ozone is an aggregation of atoms of Oxygen into molecules.

In 1858 Clausius advanced the hypothesis that ordinary Oxygen consists of a molecule of two combined atoms, whilst Ozone is in the state of *free* atoms. The researches of recent investigators have induced him to modify his opinion. He now holds that Ozone is a combination between an atom and a molecule of Oxygen.

Allotropic forms of Carbon, Phosphorus and Chlorine.

If the differences between Ozone and its parent Oxygen are great, they are not more if so striking, as are those between the three allotropic modifications of Carbon—viz. lamp-black, graphite or plumbago, and the diamond—or as the widely-dissimilar forms of vitreous and red Phosphorus, the former, when dry, igniting at the temperature of a summer's day, whilst its brick-red modification can be carried with safety in the waistcoat pocket. Draper

of New York has shown[1] that Chlorine, a gas which bears the closest analogy with Ozone, on account of the powerful bleaching, disinfecting, deodorizing, and other powers common to both, may exist in an active and passive condition. In the former state it would appear to possess all its well-known properties, and in the latter even its most energetic affinities disappear. As Ozone, then, is an active allotropic form of Oxygen, so Chlorine would seem to be an active allotropic condition of passive Chlorine.

M. Baudrimont, indeed, is of opinion that all bodies may exist in at least two allotropic forms.

Thanks to the researches of Andrews,[2] Tait,[3] and Soret,[4] a reply to the question with which this chapter commences can now be given with confidence. Our present knowledge enables us to conclude that Ozone is simply a condensed or allotropic form of Oxygen, and that they are mutually convertible, the one into the other, without the production of any other body.

Positive and Negative Ozone.

As electricity exists in two distinct states, a positive or vitreous and a negative or resinous, it has been surmised that Ozone may exist in two conditions. Ozone has been considered by Scoutetten to be produced only when Oxygen is *positively* electricized, for the following reasons:—

1. In electrolysis the Oxygen always appears at the positive pole.

2. The surface of water, such as the sea, lakes, etc., disengages a considerable quantity of Oxygen, and positive electricity is simultaneously produced by the evaporation of the water at the moment when it separates itself from the salts held in solution. Under these conditions Ozone is developed as a result of the influence of the positive electricity on the Oxygen.

[1] Silliman's *American Journal of Science*, vol. xlix. p. 346; 1845.
[2] *London Philosophical Transactions*, 1856, p. 1.
[3] *Ibid.*, 1860, p. 113.
[4] *Comptes Rendus*, lxi. 941; lxiv. 904.

3. Pouillet has shown that plants evolve positive electricity.

4. The gas exhaled by plants is not simple Oxygen, as has been generally supposed, but electricized Oxygen. An American, Dr. J. Schiel of St. Louis, believes, on the contrary, that Ozone is Oxygen in a highly electro-*negative* condition. He found that ozonised air or Oxygen may be combined with non-ozonised air or Oxygen to form a galvanic circuit, in which the ozonised gas is the electro-*negative* element.

If positive and negative electricity be allowed to impinge on ozonoscopic paper, it will be found that there is no difference in the effects of the two kinds of electricity.

Preparation of Ozone.

Ozone, then, the formula of which is $O_2O = 48$, is an allotropic modification of Oxygen, which is formed in many ways, but is not obtained in a pure and isolated form, being always mixed with a certain proportion of Oxygen.

It may be prepared—

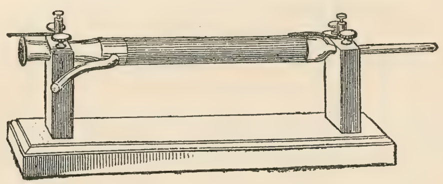
1. By passing through Oxygen or air a number of electric sparks.—Many apparatuses have been constructed for producing Ozone in this manner. One of the simplest is the "tube ozoniseur" of M. Houzeau, which he brought under the notice of the French Academy in February 1872. It consists of a glass tube, similar to those employed in the collection of gases, in the interior of which is placed a copper, lead, or (better still) a platinum wire from $15\frac{1}{2}$ to $23\frac{1}{2}$ inches long, one of the extremities of which makes its exit through a lateral orifice arranged at the superior part of the tube. This opening is closed with wax, or hermetically sealed by the aid of the gaslight. On the outside of this tube another wire of the same metal, and about the same length, is rolled, so as to follow the direction of the wire within. These two wires, being placed in communication with the poles of a Rum-

The "tube ozoniseur."

korff's coil furnishing sparks from three-quarters of an inch to an inch in length, a powerful ozonisation of the Oxygen, or of the air which is slowly transmitted through the tube, is immediately produced. If Ozone is required in larger quantity, Siemens' Ozone tube should be employed. It is composed of a glass cylinder, about the size of an ordinary test-tube, lined on the inside with tinfoil, which is enclosed and fixed in an outer cylinder coated on the outside with the same material.

Siemens' Ozone tube.

PLATE 1. *Siemens' Ozone Tube.*



The ends of the large cylinder are closed with corks perforated for the admission of small glass tubes. The "Tube" is a sort of Leyden jar, through which Oxygen or air is drawn by means of a bladder, india-rubber bag, or aspirator. To ozonise the air in its passage, it is simply needful to pass electrical sparks through the chamber. This is accomplished by attaching the fine platinum wires, which are connected with the coatings of tinfoil on the two cylinders, to the poles of a large induction coil. The complete arrangement has been well represented in Plate 2 by Mr. Orrin Smith.

Wright's Ozone tube.

Professor Wright of Yale College has described[1] a simple instrument for the rapid preparation of a great amount of Ozone with Electricity of high tension, to be used in conjunction with Holtz's electrical machine. It consists of a straight glass tube, into the extremities of which are passed Copper wires, and through which air or Oxygen is sent.

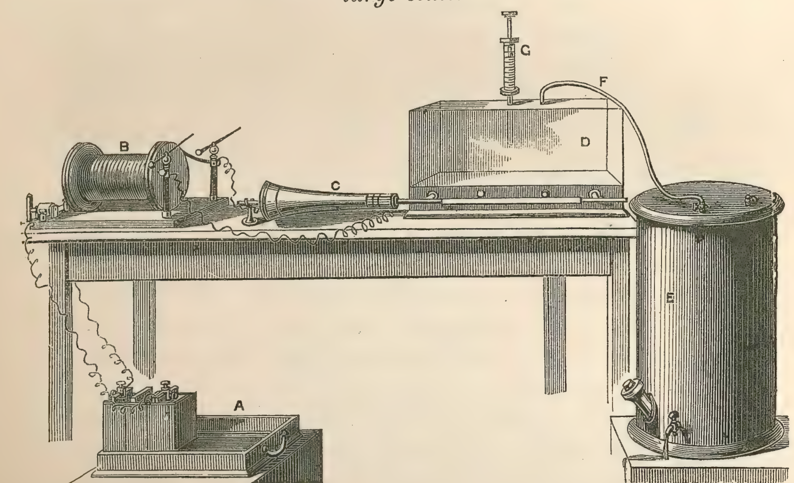
Beanes' Ozone generator.

Mr. Edward Beanes has designed, whilst Mr. Apps and Mr. Ladd have constructed, an apparatus whereby

[1] *American Journal of Science and Arts*, July 1872.

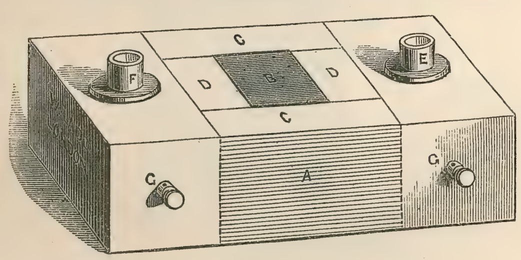
Ozone may be produced in very large quantities for commercial purposes, such as the decolorization of sugar, oils, rags, etc. (*Vide* Plate 3.)

PLATE 2. *Arrangement for the production of Ozone on a large scale.*



A, Battery; B, Induction Coil; C, Ozone generator; D, Chamber for receiving ozonised air; E, Gas-holder for reserved ozonised air; G, Pump for extracting air.

PLATE 3. *Beanes' Ozone Generator.*



A, Glass Plates carrying squares of tinfoil.
B, Uppermost square of tinfoil.
CC, Strips of Glass separating,
DD, Plates of Glass.
E, Inlet.
F, Outlet.
GG, Binding Screws for connection with poles of induction coil.

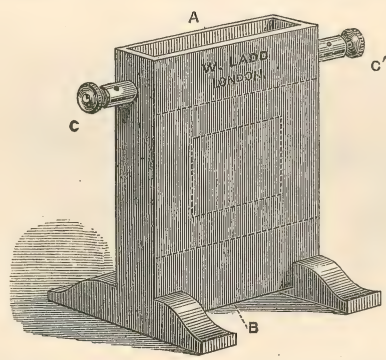
Air, forced into the instrument at E by means of a bellows or other blowing machine, passes between the plates, and makes its exit at F.

Ladd's modification.

Mr. Ladd has introduced a modification of Beanes' Ozone generator, adapted for the purification of the air of mines, hospitals and other public buildings. It consists of a mahogany box 14 inches by 7 inches by $1\frac{1}{2}$ inch, on the inside of which are six sheets of glass, each sheet having a square piece of tinfoil pasted on one side of it. These plates are separated from one another by slips of glass placed along two edges, so as to leave a series of broad channels of a depth equal to the thickness of each plate. Oxygen or ordinary air, in passing between these plates, becomes strongly ozonised, when the binding screws of this instrument are placed in connection with the induction coil. The box is open above and below to permit of a free passage of air, in order that fresh Ozone may be uninterruptedly made.

In this apparatus the Ozone falls down, by reason of its greater density, as rapidly as it is formed. In thus giving place to air from above, a current is created.

PLATE 4. *Ladd's Modification of Beanes' Ozone Generator.*



A, Upper opening. B, Lower opening.
C, Binding screw connected with the 1st, 3d, and 5th sheets of tinfoil.
C′ ,, ,, 2d, 4th, and 6th ,,
The dotted lines show the position of the glass plates, and the square outline in the centre that of the tinfoils.

MM. L'Hote and St.-Edme, having critically examined this generator, thus report concerning it to the French Academy of Sciences:[1]—"The instrument manufactured by Mr. Ladd furnishes from the air a continuous supply of Ozone quite free from all nitrous compounds which are injurious to the organs of respiration." A difference in the results produced by the passage of the "direct electrical spark" and the "spark of condensation" has been dwelt upon by French savants. It may be said generally, that the direct spark passing through air nitrifies it, forming only a minute quantity of Ozone; whilst the spark of condensation, produced in Beanes' apparatus and in the "tube ozoniseur," is associated with the development of a maximum of Ozone and a minimum of Nitrous Acid.

The "direct electrical spark," and "spark of condensation."

The amount of Ozone produced in Oxygen or air by the electrical discharge varies according to the mode of its transmission, the length of the spark, and other circumstances. Andrews and Tait have shown that the maximum effect is obtained with a *silent* discharge. It has been found that sparks about an inch long generate twice as much Ozone as sparks of ·15 to ·19 of an inch in length. Houzeau states that his "tube ozoniseur" possesses the power of charging Oxygen with Ozone to the extent of from $\frac{9}{10}$ gr. to $1\frac{8}{10}$ gr. in the litre (61 cub. in.), according as the operator employs a temperature of 59° F. above or 22° F. below zero.

Obtained in a more or less concentrated state.

It is commonly believed that, for the production of Ozone by means of electric currents through Oxygen or air, the passage of a spark through either medium is a *sine quâ non.* It has been long known to those who have paid much attention to this subject, that the passage of the electric *spark* immediately destroys a large proportion of the Ozone which had been previously produced. MM. Fremy and Ed. Becquerel have affirmed that Oxygen acquires the

[1] "Sur la génération de l'ozone dans l'oxygène et dans l'air influencés par l'étincelle electriquè de condensation."—*Comptes Rendus*, September 21, 1868.

power of rendering Iodized Starch paper blue, when this gas is submitted to the inductive influence of a series of sparks passed over the external surface of the tube which encloses it. Meissner in his most recent researches, an account of which has just issued from the press,[1] expresses his doubts as to whether the production of Ozone is connected with the process of discharge, and thinks that its manifestation by the aid of electricity and Oxygen is a question rather of the effect of the tension or force of the discharge. To ascertain this point, he performed a series of experiments with hollow tubes of glass covered with tinfoil, through which Oxygen could be passed, and fitted with arrangements, by which any chemical, thermal, or optical changes, or changes of pressure, resulting from the charging and discharging of the same, could be easily observed. His experiments seem to show that the intensity of the Ozone reaction, after the charging and after the discharging of one of these glass tubes, is dependent—

Meissner's researches.

1. On the amount of the charge which is communicated to or withdrawn from the tube; and,

2. On the velocity with which a certain charged condition of the tube is produced or removed.

He is, moreover, of the opinion that the amount of test coloration does not so much depend upon the magnitude of the charge discharged, and on the mode in which it is discharged, as upon the way in which the charged condition is produced. He states that when a suddenly produced charge is *gradually* discharged (by applying a half conductor), the reaction is less than if it is *suddenly* discharged. Meissner has clearly demonstrated that Ozone can be produced by electricity without the passage of a spark through Oxygen. He asserts that the simple charging and discharging of the sides of a glass vessel or tube containing Oxygen is sufficient; its production, in these circumstances, being occasioned by the dis-

The passage of a spark is not necessary.

[1] "Untersuchungen über die elektrische Ozonerzeugung und über die Influenz-Elektricitat auf Nicht-Leitern:" Gottingen, 1871.

turbance of electricity under the influence of induction on the side of the vessel, at the moment of charge and discharge. He points out some very interesting facts as to the influence of the condition of the exterior surfaces of non-conducting covers (such as wax, sealing-wax, etc.) of the vessels in which Oxygen is exposed to the charging and discharging influence of electricity. He found, for example, that tubes containing Oxygen, subjected to electric charges and discharges, behaved differently, according to the shape of the covers with which they were provided.

Amount of Ozone influenced by form of covers of vessels wherein it is made.

PLATE 5.

Fig. *a.*

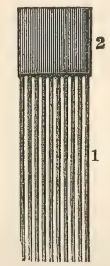


Fig *a.* Longitudinal section of tubes.
1. Uncovered } with
2. Covered } wax.

Fig. *b.*

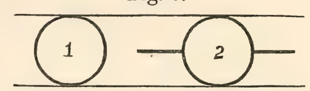


Fig. *b.* Transverse section of tubes magnified.
1. Tube as in Fig. *a.*
2. Same tube with glass wings affixed to the sides.

Fig. *c.*

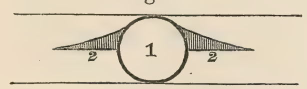


Fig. *c.* 1. Winged tube, with sealing-wax supports to each wing (2).

Fig. *d.*

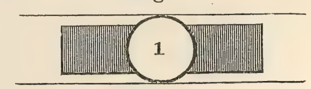


Fig. *d.* 1. Similar tube, with thick wings of wax, each wing having a sharp edge or angle.

Fig. *e.*

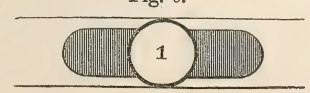


Fig. *e.* 1. Similar tube with wings, the edges or angles of which have been rounded off.

In Fig. *a* the production of Ozone, when a number of parallel tubes were uncovered, was *nil;* but, when they were coated and united together by a thin covering of

wax, was appreciable. Ozone was indicated in larger amount when the tubes were furnished with lateral glass wings (as in Fig. *b*). In still greater quantity was Ozone formed when sealing-wax supports were added to the glass wings (as in Fig. *c*). It was formed in maximum quantity when the tubes were provided with thick wax wings (as in Fig. *d*), the edges of which were sharp and angular. When the angles were removed (as in Fig. *e*) no Ozone at all was produced. On the restoration of the edges, Ozone was again formed in abundance.

M. Boillot's mode of preparing Ozone.

The manufacture of Ozone by Electricity without the production of sparks is advocated by M. A. Boillot.[1] He employs for this purpose two tubes, one about $\frac{1}{2}$-inch in internal diameter and $12\frac{1}{2}$ inches long, and the other $\frac{3}{10}$-inch in diameter and $11\frac{1}{2}$ inches in length. The extremities of the latter are sealed by the flame. The external surfaces of both of these tubes are covered with powdered coke, which is rendered adherent by the admixture of gelatine. When the smaller tube is inserted within the larger one, sufficient space is left for the passage of a current of Oxygen, the velocity of which can be regulated. The tubes are enveloped by a glass insulator. One of the cylindrical surfaces of carbon is placed in connection with one of the poles of an induction coil attached to four of Bunsen's elements, and the other surface with the other pole of the same, by means of platinum wires.

Electrolysis.

2. By the electrolysis of acidulated water.—Baumert obtained by the electrolysis of water, acidulated with Sulphuric Acid, ·0154 grain of Ozone in 150 litres (9150 cubic inches) of odorous Oxygen, and the same amount in 10 litres (610 cubic inches), when Chromic Acid was substituted for the Sulphuric Acid.

M. G. Planté states[2] that in this process more Ozone is obtained by employing lead electrodes.

[1] "Préparation de l'Ozone, au moyen d'un nouveau mode de production des effluves électriques"—*Comptes Rendus*, July 22, 1872.

[2] *Comptes Rendus*, July 23, 1866.

Phosphorus.

3. By placing a stick of Phosphorus scraped clean in the bottom of a vessel of air containing sufficient tepid water to half submerge it.—After the lapse of an hour or two the production of Ozone attains its maximum. The Phosphorus should then be withdrawn, and the enclosed air well washed to remove the Phosphoric Acid. If the Phosphorus be allowed to remain, the Ozone by degrees disappears, owing to its combination with this metalloid. It is sometimes prepared in the laboratory by slowly transmitting a current of moist air through some Woulfe's bottles, each containing a few pieces of Phosphorus. On its exit it is purified by passing it through water or a dilute alkali.

Small simple Ozone-makers have been devised by Dr. Barker and Dr. Moffat. In Dr. Barker's instrument air is passed over Phosphorus which is partly immersed in water.

Potassium Permanganate and Sulphuric Acid.

4. Ozone is formed by the action of strong Sulphuric Acid upon Potassium Permanganate.—Böttger[1] mixes very gradually three parts of the acid with two parts of the salt. The mixture, he states, will continue to give off Ozone for several months.

This mode of preparing Ozone is preferred by me for the purification of the air of hospitals, halls for public assemblies, etc. The development of Ozone by electricity is expensive requiring apparatus; and by the semi-immersion of Phosphorus, is attended by the inconvenience of being too much dependent on the surrounding atmosphere, and of diffusing a certain amount of Phosphoric and Phosphorous Acids.

Pulverization of water.

5. By dispersing water in a pulverized form through the air.—(*Vide* Experiments of M. Morin, p. 110.)

Ether vapour and heated glass rod.

6. By the introduction of a hot glass rod into a vessel of air through which the vapour of Ether has been diffused.—The preparation of Ozone in this manner is somewhat troublesome, on account of the difficulty experienced in obtaining the proper temperature. If the

[1] *Zeitschrift für Chem. und Pharm.* Bd. iii. s. 718.

rod is not sufficiently heated no Ozone will be generated, and, if it is too hot, any that may have been formed will be immediately converted into common Oxygen. The formation of Ozone in this case, as in that where it is produced by clean moist Phosphorus, appears to be simultaneous with the partial oxidation of the acting substance.

" Ozone-carriers."

7. By the slow oxidation from exposure to light and air of certain ethers, volatile and resin oils, and other bodies, which have been denominated " Ozone-carriers," such as Sulphuric Ether, Chloroform, Oil of Turpentine, Lemons, Linseed, Cinnamon, Bergamot, and most essential oils, the Blood-corpuscle, etc.—These bodies are said to absorb Ozone without combining with it, and to possess the property of yielding it up to other substances. They bleach solutions of Indigo and other plant-colours, and give a blue colour with Guaiacum and Iodized Starch papers. Some have said that these Essential Oils which have undergone exposure do not betray the presence of Ozone but of the Peroxide of Hydrogen. The " turps " sold in the shops sometimes contains as much as 50 per cent of its volume of one of these oxidizing principles.

Ethers.

Dr. Day of Geelong[1] has advocated the employment of one of these " Ozone-carriers " for sanitary purposes. He recommends that the shirts, blankets, bedclothing, and bandages of the sick be sprinkled with an Ether which has undergone this process of oxidation.

The various kinds of Ethers differ much with respect to the amount of Ozone contained in them, as the following table will show :—

[1] *Lancet*, February 3, 1866.

TABLE 1.

Ethers, etc.	Reaction with red and blue Litmus.	Ozone Tests.	
		Iodide of Potassium.	Iodized Starch.
		No.	No.
1. Ether at least ten years old .	Acid. . .	9	5
2. Commercial Methylated Ether	Slightly acid .	3	1¾
3. Methylated Absolute Ether .	Neutral . .	4	3
4. Refined Methylated Ether .	Very slightly acid	3	2
5. Absolute Ether (Æther Purus, P.B.)	Very acid . .	10	5
6. Dr. Richardson's Ozonic Ether	Very strongly acid	11	10
7. Another spec. of absolute Ether	Very slightly acid	4	2½
8. A third spec. of absolute Ether (recently made)	Faintest trace of acidity	2½	2
9. Rectified spirit . . .	Neutral . .	½	1½
10. Chloroform	Neutral . .	0	0

It will be observed that the three ethers most highly ozoniferous are more acid than the others. Suspecting lest the Ethers yielding decidedly acid reactions might contain some acid Peroxide of Hydrogen, which decomposes Iodide of Potassium like Ozone, I tested each of them with a Sulphate of Manganese paper (which had been coloured by Ozone), and with solutions of the Permanganate of Potash and Chromic Acid.

	(*a*) Coloured Sulphate of Manganese Test.	(*b*) Solution of Permanganate of Potash.	(*c*) Solution of Chromic Acid.
1. Old Ether .	Colour slightly increased	Colour changed to brown.	Unchanged.
5. Absolute Ether	Do.	Do.	Do.
6. Dr. Richardson's Ozonic Ether .	Removal of all colour	Complete bleaching.	Blue colour produced.

Pure Peroxide of Hydrogen is characterized by the property of bleaching the Peroxide of Manganese and Permanganate of Potash tests, and of forming a blue colour with Chromic Acid. The No. 1 and 5 Ethers, like Ozone, behave in a manner quite different when submitted to (*a*)

and (*b*) tests, and are quite unable to exhibit the beautiful blue tint with Chromic Acid.

It is evident, then, that the action of Dr. Richardson's Ozonic Ether on the Iodide of Potassium tests is due to the Peroxide of Hydrogen which has doubtless been mixed with it. As Ozone is superior as an oxidizing agent to oxygenated water, the old Ozoniferous Ethers are to be preferred. Exposure to air and light seems alone necessary for the ozonisation of Ethers. This change may be conveniently effected by exposing to the light a small quantity of an Ether at the bottom of a very large, well corked bottle.

Mode of ozonising Ethers.

Mr. Ellery finds that these Ethers yield no ozonic reaction in a partial or complete vacuum, and thinks that the Ozone is not held in solution, but is generated when the Ether is associated with moist air, and during its evaporation in the air.

As deodorizers and disinfectants, Ozoniferous Ethers are very useful to physicians and nurses in their attendance on the sick. They should be sprinkled over handkerchiefs, garments, and the bed linen of fever cases. Their employment in the wards of hospitals is highly desirable. As those which should be alone employed for sanitary purposes are extremely powerful, it is only necessary to use a very small quantity at a time. A drop or two of either of the Ethers numbered 1 and 5 allowed to moisten a handkerchief, in which an Iodide of Potassium test has been wrapped, very rapidly colours it.

Other modes of preparing Ozone.

8. Ozone is said to be produced by the addition of concentrated Sulphuric Acid to the Binoxide of Barium, also during the combustion of Hydrogen, Carbide of Hydrogen, and of kindred gases, and in the processes of fermentation and putrefaction. Whenever, in fact, a chemical reaction takes place in the presence of atmospheric air, Oxygen is said to be ozonised. The statement of M. Loew, to the effect that Ozone is formed by rapid combustion, is opposed by Dr. J. D. Boeke of Alkmaar. On repeating Loew's experiment, with this slight modification, that a stream of *Oxygen* instead of *air* was blown through the luminous flame of a Bunsen's burner into the mouth of a glass balloon, he found that the peculiar odour, and the property of colouring the Iodized Starch test which were acquired, were due to the production of a compound of Oxygen and Nitrogen (probably the Dinitric Trioxide or Nitric Dioxide).[1]

Some Frenchman has stated that Ozone may be developed by the attrition of pieces of quartz or of flint. Dr. Hare has had an apparatus constructed in order to decide this question. He discovered that the odour perceptible during the friction of siliceous stones is not due to Ozone.[2]

Properties of Ozone.

Ozone is insoluble in solutions of the acids and alkalies, in alcohol, ether, essential oils, and in water. It quickly purifies the last-named fluid if charged with any organic matters.[3] Andrews states that it is $3\frac{1}{2}$ times heavier than Oxygen, into which it may be reconverted by heat, and by the catalytic action exerted on it by Peroxide of Manganese, Peroxide of Lead, black Oxide of Copper, or Peroxide of Silver.

An oxidizer.

It acts on most substances as an *oxidizing* agent of great power, converting Indigo into Isatin, the black Sulphide of Lead into the white Sulphate of Lead, and the yellow Ferrocyanide into the red Ferricyanide of Potassium. The metals, Arsenic, Antimony, Iron, Manganese, Zinc, Tin, Lead, Bismuth, Silver, and Mercury, are oxidized by Ozone. It also transforms many of the lower Oxides into Peroxides. Schönbein states that Nitr*i*tes can be changed into Nitr*a*tes by Ozone only, whilst Antozone and neutral Oxygen have no action on these salts.

[1] *Quarterly Journal of Science*, October 1870.

[2] Silliman's *Journal of American Science*, vol. xii., 2d Series, 1851.

[3] The so-called Ozone-water of Krebs and Kroll does not contain Ozone, but Peroxide of Hydrogen.

A deoxidizer.

It *deoxidizes* or reduces a small class of bodies, such as the Peroxides of Hydrogen and Barium which become water and baryta respectively, being at the same time itself converted into Oxygen. When brought into contact, under certain circumstances, with Ammonia, it forms, according to Dr. Wood, a specific compound or salt—an "Ozonide of Ammonium."

The polarizing effects of Ozone upon Platinum and Gold are very curious. A slip of either of these metals acquires a *negative* polarity after being immersed a few seconds only in an ozoniferous atmosphere.

Its corrosive powers, and its property of destroying most organic substances, are remarkable. In its concentrated state, it possesses bleaching properties superior to Chlorine itself. The experiments of Baumert, Schönbein, and Gorup-Besanez, show that wood, straw, cork, starch, vegetable colours, caoutchouc pure and galvanized, the fats and fatty acids, alcohol, and albumen, are oxidized by this agent.[1]

Effect on the blood.

Ozone is thought by some to be absorbed by the blood-corpuscles with great rapidity, Oxygen being liberated. Kühne, on the contrary, is of opinion, that the blood-globules ozonise the Oxygen with which they come into contact, without themselves undergoing any change.

Powerful purifying agent.

Ozone possesses the power of destroying by oxidation the putrid exhalations, such as Sulphuretted Hydrogen, etc., from decomposing organic matters. In illustration of its deodorizing and purifying effects, the following experiment was performed by Drs. Wood and Richardson:—In 1854, a pint of the blood of an ox coagulated was exposed to the air until it was quite putrid, and the clot was softening. At the close of the year, the clot having redissolved as a result of alkaline decomposition, the blood was a most offensive fluid. In 1862, the fluid was found to be so offensive as to produce nausea when the gases evolved

[1] For full details respecting what may be called the Chemistry of Ozone, vide *De l'Ozone*, a thesis by Dr. E. Boeckel of Strasburg.

from it were inhaled. Drs. Wood and Richardson subjected it to a current of Ozone from Siemens' apparatus. Gradually the offensive smell passed away, and the fluid mass became quite sweet. The dead blood, moreover, coagulated as the products of decomposition were removed, and this so perfectly, that the new clot exuded serum.

Comparison between the Properties of Ozone and of Oxygen.

The differences between the properties of Ozone and its derivative have been usefully summarized by Houzeau in the following table:—[1]

TABLE 2.

Properties of Oxygen in a Free State at the temperature of 59° F.	Properties of Ozone in a Free State at the temperature of 59° F.
A colourless and tasteless gas .	A colourless gas possessing a powerful odour and a flavour of lobsters.
Without action on blue litmus	Decolorizes blue litmus.
" India rubber	Corrodes India rubber.
Does not oxidize silver . . .	Oxidizes silver.
Does not decompose Potassium Iodide	Rapidly acts on Iodide of Potassium, and places Iodine at liberty.
Without action on Ammonia .	Consumes instantaneously Ammonia, transforming it into the Nitrate.
Without action on Phosphuretted Hydrogen	Combines immediately with Phosphuretted Hydrogen, with emission of light.
Does not react on Hydrochloric Acid	Decomposes Hydrochloric Acid, liberating its Chlorine.
A feeble oxidizing agent . .	A powerful oxidizing agent, and an energetic bleacher.
Very stable at all temperatures	Destroyed at high temperatures.

[1] Article "Ozone" in *l'Encyclopédie de l'Agriculteur*, tome xi.

WHAT IS ANTOZONE?

Schönbein's investigations.

OXYGEN is capable, according to Schönbein, of assuming three different conditions—viz. two contrary active states and one passive, which have been named respectively Ozone, Antozone, and Neutral Oxygen. There are several means by which Neutral Oxygen may be chemically polarized and depolarized. This polarization takes place when ordinary Oxygen enters into combination with organic or inorganic substances in the presence of moisture. Antozone is Oxygen in the positively polar state, and may be represented thus: $\overset{+}{O}$. He obtained Antozone by treating finely powdered Peroxide of Barium with cold monohydrated Sulphuric Acid. A gas is evolved which both Houzeau and Schönbein considered at first to be Ozone, but which possesses different properties. Schönbein stated that it blues Iodide of Potassium and Starch, and smells somewhat like Ozone; but, when agitated with water, loses its odour completely, and forms the Peroxide of Hydrogen—a reaction which Ozone does not produce. He informed the world that Antozone may be distinguished from Ozone by papers imbued with a solution of the Sulphate of the Protoxide of Manganese, which become brown in Ozone, from the formation of the Peroxide of Manganese: in Antozone, however, this reaction does not take place. On the contrary, *Sulphate of Manganese papers browned by Ozone are bleached by Antozone.* He claimed the credit of having isolated Antozone in 1861, but has never been able to obtain it without a slight admixture of Oxygen.

It was erroneously reported in 1865 that he had liquefied Antozone, and had determined its physical properties, as specific gravity, etc.; also that Antozone, when mixed with Ozone, is exploded by the non-luminous rays of the spectrum and by positive, but not by negative, electricity.

Schönbein, in his work on "The action of Oxygen on the Blood," expressed his conviction that the blood-globules, like Phosphorus, are endowed with the property of chemically polarizing the Oxygen of the air, with which they are brought into contact in the lungs, and of thus splitting it up into Ozone and Antozone.

$$\text{Oxygen}\left\{\begin{array}{l}\text{Ozone—consumed in different oxidations within the body.}\\ \text{Antozone—transformed by blood-corpuscles into}\ \ .\ \ .\ \left\{\begin{array}{l}\text{1. Ozone.}\\ \text{2. Peroxide of Hydrogen by combining with the water of the blood.}\end{array}\right.\end{array}\right.$$

Polarization of the atmospheric Oxygen by the blood-corpuscle.

He did not succeed in finding either Ozone, Antozone, or Peroxide of Hydrogen (Antozone + water) in a free state in the blood. He discovered the Peroxide of Hydrogen, however, in urine, to which he ascribes the rapid oxidation of that fluid. Because Tr. of Guaiacum, which is blued by many bodies besides Ozone, is only thus coloured by Peroxide of Hydrogen when blood-corpuscles are present, he believed that, through the instrumentality of these globules, the Antozone of the Peroxide of Hydrogen is changed into Ozone which indicates its presence by blueing this resin.

Test for blood.

The remarkable reaction which takes place when Peroxide of Hydrogen and Tr. Guaiaci are added to blood has been employed at the suggestion of Dr. J. Day by authorities on Medical Jurisprudence as a test for stains occasioned by this fluid. This gentleman, who endorses Schönbein's views as to the constitution of Oxygen, thinks that pus-globules are possessed of the faculty of transforming Antozone into Ozone more readily than blood-corpuscles. He has noticed that Tr. Guaiaci, which has

Test for pus.

been exposed for some time to air and light, and in this manner absorbed in his opinion a minute trace of Antozone, gives a blue reaction with pus without the assistance of Peroxide of Hydrogen, whilst blood is unaffected by it. If the statement is confirmed, this test, capable of distinguishing between pus and blood, will prove of great advantage, not only in medico-legal inquiries, but in medical and surgical diagnosis.

The fluor-spar of Wölsendorf.

Schönbein states that the smell perceived on rubbing the blackish violet-coloured fluor-spar from the stratified granite of Wölsendorf in Bavaria is due to the development of Antozone, which he found in the proportion of $\frac{1}{5000}$th of the weight of the spar. On the other hand,

Schrötter's experiments.

Schrötter contends[1] that the odour is that of Ozone. The maximum amount, which he estimated in several specimens, was ·02 per cent. On passing a stream of strongly ozonised air over a piece, the spar was found to have absorbed more Ozone. A strip of Iodized Starch paper held near this spar, after it has been rubbed in the mortar, becomes immediately coloured.

Meissner's researches.

Schönbein's views[2] have received support from the observations of Meissner, who, in 1863, discovered[3] that if well dried electrified Oxygen or air be passed through water, or into a moist atmosphere, a cloud or mist is formed. He satisfied himself, by numerous experiments, that electrified air contains Ozone and a substance he

Atmizone.

named Atmizone (*ατμιζω*, to smoke), and that this phenomenon of mist is due to the latter. This mist-forming gas was subsequently found to be identical with Schönbein's Antozone. He succeeded in isolating Antozone by

Mode of preparation.

electrifying a perfectly dry stream of Oxygen gas, and depriving it of its Ozone by means of a solution of Iodide of Potassium. When the gas which emerges from this

[1] *Sitzungsberg. der Akad. de W. zu Wien.* Bd. xli.
[2] Schönbein's speculations relative to Antozone may be found *in extenso* in the *Philosoph. Mag.*, 1858.
[3] *Untersuchungen über den Sauerstoff.*

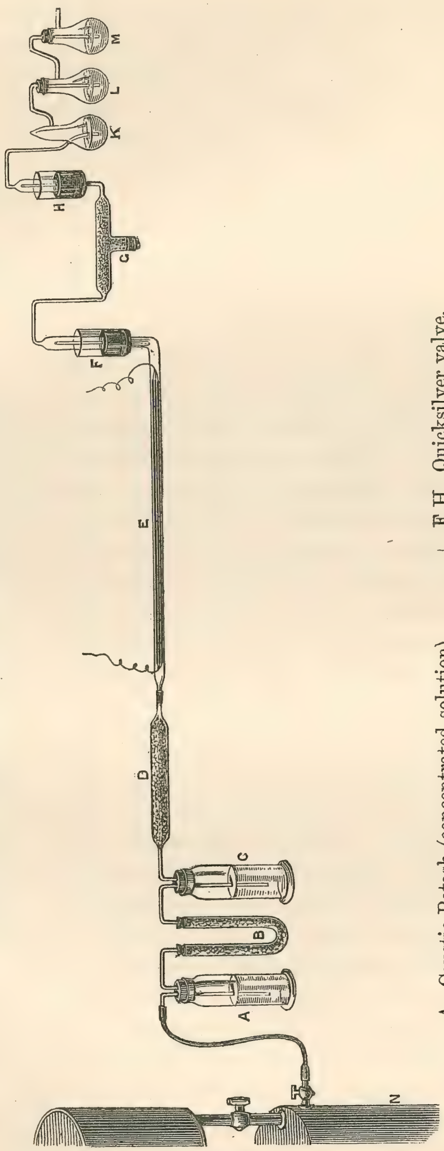
solution is passed through pure water, a dense white mist appears, the aqueous vapour becoming condensed in the form of little vesicles which remain suspended (*vide* Plate 6). The Oxygen gas passing through A B C D is deprived of any Chlorine, Carbonic Acid, Ammonia, and vapour of water which it may contain. The Antozone cloud is formed over the water in M. That Ozone in a free condition does not form the clouds with the vapour of water is shown by the fact that clouds are never seen in K. The mist can be poured like Carbonic Acid from one vessel to another.

Antozone is, according to Meissner, the cause of the cloud in tobacco-smoke, the smoke of chimneys, of gunpowder, of the fumes emitted by Phosphorus when exposed to the air. The copious rains which follow great battles have been supposed to be due to some extent to this body, the decomposition of the cloud of Antozone-water being either a cause or an effect of the electrical excitement of the air. The white vapours obtained by the slow combustion of Phosphorus in the air are, however, in the opinion of Schönbein and Ozann, the Nitrite of Ammonia. Meissner states that ozoniferous moist air retains its cloud-compelling property longer than that which contains no Ozone, and that dry ozonised air preserves it still longer. He considers that every cloud and mist of our atmosphere is formed under the direct influence of Antozone, being a physical aggregate of Antozone and vapour of water. He says that clouds can only be formed in gases containing Oxygen, the condensation of aqueous vapour in gases free from Oxygen occurring in the form of solid globules, which immediately subside by reason of their weight. Peroxide of Hydrogen is regarded by him as a chemical compound of Antozone and water. He, like Schönbein, noticed the tendency of Antozone to lose its characteristics and become converted into Oxygen. The Germans employ the almost untranslatable word "ablingen" to denote this property of evanescence.

Statements of Meissner.

Clouds alone formed in gases containing Oxygen.

PLATE 6. *Meissner's Apparatus for the Production of Antozone.*



A, Caustic Potash (concentrated solution).
B, Chloride of Calcium.
C, Sulphuric Acid.
D, G, Phosphoric Acid (Anhydrous).
E, Tube in which the Oxygen is subjected to the influence of Electricity.

F H, Quicksilver valve.
K, Distilled Water.
L, Solution of Iodide of Potassium.
M, Distilled Water.
N, Gasometer filled with Oxygen.

Meissner, finding that the Antozone produced by his method did not influence Iodide of Potassium and Starch tests, thought that there must be two kinds of Antozone. He writes, "Between the Antozone produced from the Peroxide of Barium, and the Antozone formed by electrifying Oxygen, a great distinction must be made; the former, according to Schönbein, decomposes Iodide of Potassium like Ozone, whilst the latter is unaffected by a solution of Iodide of Potassium, through which it is passed to separate from it the Ozone." He proceeds to comment on this extraordinary difference, and finally suspects that the decomposition of the Iodide of Potassium may be due to the action of the concentrated Sulphuric Acid employed in the formation of the Antozone from the Peroxide of Barium. Messrs. Nasse and Engler have shown that both Ozone and the so-called Antozone are produced when these substances are brought into contact with one another; that to the presence of Ozone the blueing of the Iodized Starch tests is due, whilst the pretended Antozone is to be recognised by the tendency of the gas to form clouds with water, and by the discovery of Peroxide of Hydrogen in the water through which it has for a long time passed.

Antozone is generally looked upon as a principle which possesses an odour similar to that of Ozone, produces when inhaled nausea and choking, and which neither colours an Iodized Starch nor a Tr. Guaiacum test, both of which are tinted by Ozone. Incapable of oxidizing bodies which are easily oxidized by Ozone, such as Phosphorus, Iodide of Potassium and Pyrogallic Acid, or of converting the Ferro- into the Ferri-cyanide of Potassium; it is regarded as a modification of Oxygen, to which belongs the power of oxidizing water and converting it into the Peroxide of Hydrogen with the simultaneous development of clouds, a feat which Ozone is not able to accomplish, although it may be allowed to remain in contact with this fluid for weeks. Whilst Ozone is insoluble in water, Antozone is said to have a powerful affinity for it. Its properties.

Some, in harmony with Brodie, have set at rest the question "What is Antozone?" by replying, "Antozone is an entire myth."

Opinions of Babo and Weltzien.

According to Babo[1], the fumes described by Meissner are produced only in presence of Nitrogen or oxidizable substances, and ozonised Oxygen free from this gas generates with water neither cloud nor Peroxide of Hydrogen. He agrees with Weltzien[2] in thinking that the so-called Antozone is simply the Peroxide of Hydrogen. The recent researches of Messrs. Nasse and Engler[3] have led them to repudiate the idea that Antozone is a modification of Oxygen, and to confirm the statements of their fellow-countrymen just referred to. Their experiments show—

Nasse and Engler's researches.

1. That Ozone and Antozone are not formed simultaneously, as Schönbein has affirmed, when Oxygen is subjected to the action of electricity;

2. That the so-called Antozone is only produced when Ozone suffers decomposition from the presence of water; and,

3. That the pretended Antozone is undoubtedly the Peroxide of Hydrogen diffused through a large quantity of air or Oxygen.

To follow the various observers through their elaborate and complicated experiments made with the view of deciding these moot points, would be beyond the scope of this work. Two or three of them must, however, be referred to on account of their extreme importance.

One of the foundations on which Schönbein's doctrine (which has been supported by Meissner) of the chemical polarization of Oxygen has rested, has been the assumption that Ozone and Antozone are produced simultaneously. Nasse and Engler found that, by passing an ozonised current of Oxygen through a tube containing dry Zinc-Sodium, the Ozone is removed just as it is when transmitted through a solution of Iodide of Potassium, but the so-called Antozone is unaffected. On bringing such a current after its exit from the Zinc-Sodium tube into contact with

[1] *Annalen der Chemie und Pharmacie*, Suppl. Bd. II. 293.
[2] *Ibid.* CXXXVIII. 163. [3] *Ibid.* May 1870.

water, the presence of Antozone should have been manifested by the formation of clouds, if Ozone and Antozone are simultaneously produced. None, however, could be detected. The so-called Antozone is removed from air containing it, by its passage through a tube containing Chloride of Calcium, which salt has no effect on Ozone. These experimenters conducted an electrified stream of Oxygen first through a Chloride of Calcium tube (which retained the Antozone), then through a solution of Iodide of Potassium (to collect the Ozone), and, lastly, through and over water. If, they argued, Ozone and Antozone are formed simultaneously in the tube where the Oxygen is subjected to the influence of electricity, clouds should not under these circumstances appear. Clouds, however, did manifest themselves, and in as pronounced a manner after as before the insertion of the Chloride of Calcium tube.

In confirmation of the conclusions arrived at by these Germans, we cannot fail to observe that the distinctive tests of Antozone are those characteristic of the presence of Peroxide of Hydrogen—*e.g.* the so-called Antozone is said (1) to bleach a Sulphate of Manganese test which has been rendered brown by Ozone. The Peroxide of Hydrogen bleaches it. It is said (2) to decolorize a solution of Permanganic Acid which Ozone on the contrary browns. Peroxide of Hydrogen decolorizes it. It is declared (3) to lack the power, which is possessed by Ozone, of converting the Ferro- into the Ferri-cyanide of Potassium. Peroxide of Hydrogen has no effect on the former salt.

Meissner's later researches.

Meissner published in 1869[1] a work which consists of two parts, one being on electrified Oxygen, and the other on the quantitative determination of Ozone, and the diminution of volume on the electrization of Oxygen. In it are found certain passages which seem to qualify his former assertions with respect to this pillar on which Schönbein's theory rests. He writes—"Formerly I maintained that, without any change in the original proportions of the Ozone and Antozone contained in electrified Oxygen, a slight for-

[1] *Neue Untersuchungen über den elektrisirten Sauerstoff:* Gottingen.

mation of clouds might take place, which statement I must withdraw, as it cannot be sustained by my later experience. Under certain conditions of quantity and density of the two components of electrified Oxygen, no formation of clouds can take place. The amount of Ozone in proportion to the amount of Antozone must be diminished in order that the clouds may be produced. They will be formed proportionally stronger, as the relative diminution of the amount of Ozone is greater." His object in this recent publication on the subject from the Fatherland is to show—

1. That the cloud contains neither Nitrogen (as Babo has asserted), Chlorine, Hydrogen, nor Carbonic Acid, but is simply Oxygen.
2. That in the electrization of Oxygen the presence of aqueous vapour is not necessary for the manifestation of this nebulous appearance.
3. That the Iodide of Potassium employed for the absorption of the Ozone from the Oxygen which has been subjected to the influence of electricity, has nothing to do with this formation of cloud.

He concludes by expressing the opinion that aqueous vapour effects the neutralization of the two opposite conditions of Oxygen (Ozone and Antozone), just as the neutralization of opposite electrical states effects the discharge of electrified bodies.

Such, then, is a brief digest of our knowledge of the so-called Antozone. Schönbein's hypothesis is evidently losing ground, and is quite inconsistent with the results of Soret's experiments, which prove that Ozone, called by him the Binoxide of Oxygen, is denser than Oxygen in the proportion of 3 to 2.

DOES THE ATMOSPHERE CONTAIN OZONE?

Frankland would reply "Not proven," whilst Fremy asserts that the evidence in favour of its presence in the air is of the most doubtful character. Chevreul, Dumas, Thenard, and their disciples, have expressed their scepticism as to the value of the indications of the Starch and Potassium Iodide test. Numberless discussions have taken place as to whether or not Schönbein's ozonoscope solely registers Ozone. The conclusion of its originator, that this body alone affects it, has been combated by a great many authors, especially by M. Cloez, who have endeavoured to show that the coloration of this test, which has been attributed by meteorologists to Ozone, may partly be due to compounds of Chlorine, Bromine, Nitrogen, Iodine and to acids analogous to Acetic, acting independently or together. This chronic controversy, which had been unceasingly carried on for many years, was brought to a climax by Dr. Bérigny in 1865. This observer, having been led, after ten years of ozonometry, to doubt the existence of Ozone in the atmosphere, asked the French Academy of Sciences, on November 27th of that year, to appoint a commission in order to decide definitively—

1. Whether Ozone exists in the atmosphere;
2. Whether the tests of Schönbein, or of any one else, prove the presence of electrolytic Oxygen; and,
3. Whether any easy and reliable method of detecting it could be devised.

Commission appointed by the French Academy.

The Academy appointed a commission composed of Chevreul, Dumas, Pelouze, Pouillet, Boussingault, Le Verrier,

Statements of M. Fremy.

Vaillant, E. Becquerel, and Fremy. The last-named distinguished chemist stated on this occasion that he looked upon the oxidation of Silver as the only certain test of the presence of Ozone in the air, and he had repeatedly exposed metallic Silver to the air without obtaining any indication of it. He expressed his unbelief in the value of test-papers which were affected not only by Ozone, but by the Oxides of Nitrogen, Peroxide of Hydrogen, Formic Acid, essential oils, the acid products of combustion, and by particles of dust, all of which may be present in the atmosphere. He required a positive proof of the presence of Ozone in the air; for, seeing that Ozone is instantly destroyed by organic matters and absorbed by Nitrogen, he considered it difficult to understand how such a body can continue to exist in the air. Again, at a lecture on Ozone delivered before the Second Conference of the Society for the assistance of the Friends of Science, held in Paris on April 10, 1866, he made the following remarks:—"When it is known that the air contains Oxygen, and that the atmosphere is constantly traversed by electric discharges, it is difficult not to admit the formation of Ozone in the air. But can this body remain in it? Has any one as yet clearly proved its presence in the air? The electric discharges, which in the air transform Oxygen into Ozone, ought necessarily to effect also the combination of Oxygen with Nitrogen and produce Nitric Acid, which, in truth, is invariably found in thunderstorms."

Houzeau's researches.

The Academy seems to have overlooked the researches of Professor Houzeau of Rouen, published in its own Transactions in the years 1857, 1858 and 1865. This chemist, although somewhat imperfectly answering the first question, gives satisfactory replies to the second and third interrogations. His communications to this learned body during 1857 and 1858 were entitled—"Nouvelle Methode pour reconnaitre et doser l'Ozone," and "Preuve de la Presence dans l'Atmosphere d'un nouveau principe gazeux, l'Oxygène naissant." In the

former paper, after destroying all confidence in the trustworthiness of the Iodized Starch test as a quantitative reagent in chemical researches, he divides the bodies which act on it in a manner similar to that of Ozone into three classes:—

1. Bodies which displace Iodine by a simple substitution—*e.g.*, Chlorine, etc.;

2. Bodies which expel the Iodine from the Iodide whilst oxidizing the Potassium—*e.g.*, Peroxide of Hydrogen, compounds of Nitrogen, oxidized Oil of Turpentine, etc.;

3. Bodies which lead in an indirect manner to the decomposition of the Potassium Iodide, by operating as a predisposing force on the Iodide itself, on the elements of water and on the Oxygen of the air—*e.g.*, Acetic Acid, the vapour of which in the presence of air gives the Iodized Starch paper a blue colour.

As this test appeared to him, then, to be useless both as an ozonometer and an ozonoscope, since it is coloured by so many different bodies, and as the other agents which had been successively proposed to replace it—such as the Sulphate of Manganese, Ferrocyanide of Potassium, etc.—were for similar reasons inapplicable, he proposed to detect the presence of Ozone by the alkalinity which it produces in combining with the Potassium of, instead of by the displacement of Iodine from, the Iodide of Potassium. He points out that neither Chlorine, Bromine, nor Oxygen, at the ordinary temperatures, possesses the property of rendering alkaline a weak solution of Potassium Iodide. In the latter essay he endeavoured to show, by a process of exclusion, that the alkalinity acquired by pure neutral Potassium Iodide, when exposed to the air of the country, can be due to no other agent than Ozone. He proved that neither ammoniacal emanations, alkaline dusts, organic dusts, Nitrogen, ordinary Oxygen, nor Carbonic Acid, are concerned in this development of Potash.

The Iodized Starch tests found a defender in the

M. Sainte-Claire Deville's defence.

person of M. Ch. Sainte-Claire Deville, who refers[1] to observations made concurrently at Versailles, Le Touquet, and Saint-Léonard, which show a *parallelism* in the indications of the ozonometer.

Ozonometer of M. Jame de Sedan. Scale of MM. Bérigny and Salleron.
Observations at Versailles by Dr. Bérigny.
" Le Touquet, at the mouth of the Cauche, near Étaples, by M. Carier.
" Saint-Léonard, about 2½ miles south of Boulogne-sur-Mer, by M. Sainte-Claire Deville.

TABLE 3.

1865.	VERSAILLES.		LE TOUQUET.				SAINT-LÉONARD.	
August.	Mean Temperature.	Ozonometer 6 A.M. to 6 P.M.	Mean Temperature. N Lighthouse.	Ozonometer 6 A.M. to 6 P.M.: N Lighthouse.	Base of Lighthouse.	Mean.	Mean Temperature.	Ozonometer 6 A.M. to 6 P.M.
	Deg. Cent.	Deg.	Deg. Cent.	Deg.	Deg.	Deg.	Deg. Cent.	Deg.
6	15·8	...	16·6	17·5	18·0	17·7	15·70	14·00
7	17·4	13·5	16·8	15·5	16·5	16·0	16·44	14·75
8	16·9	18·5	15·8	13·5	13·0	13·2	16·34	15·75
9	17·7	14·5	16·2	14·5	14·0	14·2	15·26	11·75
10	19·6	4·5	18·1	9·5	12·0	10·7	18·04	10·50
11	21·9	15·0	18·6	10·0	11·5	10·7	20·02	11·25
12	20·7	15·0	18·8	14·0	16·0	15·0	17·68	12·00
13	18·6	15·5	17·3	14·5	16·5	15·5	17·62	14·25
14	17·9	15·5	17·4	10·5	11·5	11·0	16·40	13·75
15	17·9	17·5	17·6	15·5	16·5	16·0	16·96	16·25
16	17·9	20·0	16·9	14·0	15·5	14·7	16·52	15·50
17	16·0	14·0	16·4	15·0	19·5	17·2	16·14	16·75
18	17·1	16·5	16·2	12·0	16·5	14·2	...	15·00

Statements of M. Cloez.

In 1861, M. Cloez directed the attention of European savants to the behaviour of compounds of Nitrogen in contact with Potassium Iodide, and drew conclusions from his observations, tending to the admission of the existence in the air of these bodies. M. Houzeau, thus stimulated, entered on a thorough examination of the important question, as to whether Oxides of Nitrogen are or are not the

[1] *Comptes Rendus*, August 28, 1865.

cause of the changes which his tests undergo when exposed to atmospheric air.

Houzeau's further investigations.

In July 1865, he presented to the Academy a communication, "Sur les Composés Nitreux considérés comme n'étant pas la cause des altérations que l'air atmosphérique fait subir aux papiers de tournesol vineux mi-ioduré employés comme réactifs de l'ozone." After showing in this work that, of the several compounds of Nitrogen with Oxygen, Nitric Acid and Peroxide of Nitrogen are the only ones which can possibly remain in a free state in the air, he proves: (1) that Nitric Acid, in a very much diluted state, does not influence a weak solution of neutral Potassium Iodide, a fact endorsed by Professor Fellenberg and M. Rivier; and (2) that, if a mixture of air and the Peroxide of Nitrogen should come into contact with his very sensitive iodized litmus tests, the change that might possibly be induced is more readily and satisfactorily accounted for, by supposing it to be the effect of the Ozone engendered under the influence of the oxidation of the Deutoxide of Nitrogen, to which, as is well known, the Peroxide gives birth in contact with water, than by hypothetically ascribing it to the formation of a Nitrite of Potash. When the chemical activity of the air was very great, and his test-papers became deeply coloured, he never detected in it a tangible amount of a Nitrogen compound; and, when air was artificially impregnated with Oxides of Nitrogen, his ordinary iodized litmus tests were unaffected by them. With reference to the fact made out by Boussingault, that if Nitric Acid be found in rain collected at the commencement of a long and abundant shower, none was to be detected in it towards its termination, after the air had been thoroughly washed, he declares that pure country air colours his Ozone tests after as well as before the downfall. He found, moreover, that his tests became more deeply coloured when air exhibited little than when it displayed much acidity.

Observation of Boussingault.

The attempt of the French Academy at the end of

1865 to demolish the belief in atmospheric Ozone called forth a reply from M. Houzeau,[1] which was merely a résumé of his investigations. Whilst admitting that the Iodized Starch tests are liable to be affected by the various bodies enumerated by M. Fremy, he exposes the unreliability of his infallible metallic Silver test, by demonstrating that air, far richer in Ozone than the atmosphere is ever found to be, does not affect Silver. In answer to the objection that the instability of Ozone would insure its destruction as soon as it is formed in the air, M. Houzeau suggested (1) that its production may be incessant, like that of the Carbonic Acid of the air, which is always being formed and destroyed; and (2) that its state of dilution may render it to a certain extent stable. The dilution of bodies, as is well known, sensibly modifies their properties. For example, Sulphuric Acid and neutral Potassium Iodide, which react so violently on one another even when diluted with about three or four times their weight of water, may yet be mixed, without the occurrence of any change, when they have been previously dissolved in a volume of water sufficiently great, and in this state they may even be boiled together without alteration. Houzeau maintains that the only body besides Ozone which possesses the property of developing Potash at ordinary temperatures, when brought into contact with neutral Potassium Iodide, and with which consequently it may be confounded, is Peroxide of Hydrogen. In laboratory work the olfactory nerves afford a rough and ready distinguishing test, Ozone having a strong and peculiar smell, whilst Peroxide of Hydrogen is almost completely inodorous. Ozone exists in such minute quantities in the atmosphere (if it is to be considered a constituent) that this crude test is of course quite out of the question.

Houzeau's reply to the Academy.

Discovery of M. Cloez.

The discovery by M. Cloez of Nitrous Acid in air situated about a metre (39·37 in.) from the ground, and that the ordinary Iodized Starch tests are coloured by this acid,

[1] *Comptes Rendus*, Dec. 18, 1865.

even when air contains as little as ·00005 of its volume, had led others besides M. Houzeau to ascertain whether the coloration of the tests was due to Nitrogen compounds.

M. Schönbein, and the Protoxide of Thallium.

M. Schönbein employed the Protoxide of Thallium, on which Nitrous Acid has no visible action, as a test for Ozone, which it absorbs in passing to a higher state of oxidation. Carbonic Acid unfortunately acts on this substance, and, as this acid is always contained in the air, the Oxide of Thallium is, alone and unaided, useless as an agent of discrimination.

Andrews' experiments.

To prove the identity of the body in the air which decomposes the Potassium Iodide with Ozone, Professor Andrews of Belfast performed some very interesting experiments, which he communicated to the Royal Society in 1867, the most conclusive of which are thus described by him. He writes—

"It is well known that all Ozone reactions disappear when Ozone is passed through a tube containing pellets of dry Peroxide of Manganese, or other body of the same class. The same thing occurs with the substance supposed to be Ozone in the atmosphere. About 80 litres (4881·9 cub. in.) of atmospheric air were drawn, at a uniform rate, through a tube containing Peroxide of Manganese, and afterwards made to play upon very delicate test-paper. Not the slightest coloration occurred, although the same paper was distinctly affected, when 10 litres (610·2 cub. in.) of the same air, without the interposition of the Manganese tube, were passed over it. But the action of heat furnishes the most unequivocal proof of the identity of the body in the atmosphere with Ozone." It had been satisfactorily shown by Dr. Andrews (*Phil. Trans.* 1856, p. 12) that Ozone is quickly destroyed at the temperature of 522·6° F., and at 570° F. the change is instantaneous. "An apparatus was fitted up, by means of which a stream of atmospheric air could be heated to 260° C. (564° F.) in a globular glass vessel of the capacity of 5 litres (169 oz.) On leaving this vessel the air

was passed through a U-tube, one metre (39·37 in.) in length, whose sides were moistened internally with water, while the tube itself was cooled by being immersed in a vessel of cold water. On passing atmospheric air in a favourable state through this apparatus, at the rate of three litres (183·1 cub. in.) per minute, the test-paper was distinctly tinged in two or three minutes, provided no heat was applied to the glass globe. But when the temperature of the air, as it passed through the globe, was maintained at 260° C. (564° F.), not the slightest action occurred upon the test-paper, however long the current continued to pass. Similar experiments with an artificial atmosphere of Ozone—that is, with the air of a large chamber containing a small quantity of electrolytic Ozone—gave precisely the same results. On the other hand, when small quantities of Chlorine, or Nitric Acid vapour, largely diluted with air, were drawn through the same apparatus, the test-paper was equally affected, whether the glass globe was heated or not. From these experiments I consider myself justified in concluding that the body in the atmosphere which decomposes Iodide of Potassium is identical with Ozone."

Repetition and extension of them.

The importance of these experiments being very great, and their accuracy having been questioned, I have repeated them, and have arrived at analogous results. They have been, moreover, with some slight modifications, extended by me to the examination of the air during periods when Nitric Acid and Chlorine are presumed to be present in it in largest quantity—namely, during thunderstorms and during the prevalence of strong sea breezes. These experiments, details of which are given on pages 216 and 224, failed to afford the slightest indications of the presence of either of these bodies in the air, under circumstances in which they are most likely to exist as accidental ingredients.

Gorup-Besanez, in a very recent essay,[1] thus points

[1] "Ueber die Ozonreactionen der Luft in der Nähe von Gradirhäusern"—*Annalen der Chemie und Pharmacie*, February and March 1872.

The conclusions of Gorup-Besanez, and the most recent German investigators.

out the position arrived at by the most recent German investigators. The blueing of the Iodized Starch papers in the air may be due, either—

1. To Ozone;
2. „ Peroxide of Hydrogen;
3. „ Nitrous Acid and Peroxide of Nitrogen;
4. Probably to Ammonium Nitrite according to Huizinga, the accuracy of whose observations has been denied by Gorup-Besanez.

It is now generally acknowledged that neither free Nitrous Acid, Peroxide of Nitrogen, nor Nitrites, render Thallium papers brown.

When Thallium papers assume a brown colour on exposure to the air, the change can only be regarded as a proof of the presence of Ozone in it, if they can be tinted blue by Tincture of Guaiacum. (*Vide* pp. 171 and 172.) Sometimes, even when no brown colour has been produced by an exposure to the air, they will become blue when treated with Tincture of Guaiacum. It has been suggested that, when a blueing of a Thallium paper that is found colourless after an exposure occurs, an absorption by the paper of Nitrous Acid, which blues Tincture of Guaiacum very readily, may have taken place. The experiments of Huizinga and Gorup-Besanez lead them to the conclusion that "the removal of the effect of Ozone upon a Thallium paper would necessitate the active operation on it of a comparatively large quantity of Nitrous Acid." As the latter observer has found that both his Thallium and Iodized Starch papers, when suspended together in the air, often colour deeply, he justly presumes that the coloration of the latter, at such times of great chemical activity of the air, could not be due to Nitrous Acid, except perhaps in very small amount, otherwise the effect upon the Thallium paper would have been absent, as this acid is unable to render it brown. The decolorization of blue litmus papers, simultaneously exposed, also points to the same inference. Gorup-Besanez asserts that the body

contained in the air which converts Thallious Oxide into Thallic Oxide cannot be the Peroxide of Hydrogen, because Thallium paper rendered brown is decolorized by this substance. A consideration of these facts leads him by a process of exclusion to conclude that Ozone does exist in the air, and is one of the agents concerned in the coloration of the Iodide of Potassium and Iodized Starch tests when exposed to its influence.

Final reflections.

Knowing as we do that electric currents passed through air generate Ozone; that variations in the electrical condition of the atmosphere, accompanied by discharges, are continually occurring; that storms, showers, lightning, waterspouts, hurricanes, etc., are all concerned in furnishing the air with a principle which gives it chemical activity; that Ozone is produced during slow oxidations at ordinary temperatures (which processes are incessantly carried on around us); and that papers uninfluenced by any other known agent undergo the same changes, when exposed to the atmosphere, as those which are effected in them by air artificially ozonised: we are undoubtedly justified in coming to the conclusion, that some good grounds have existed for the belief in the existence of Ozone in the atmosphere. Only very recently, however, has our knowledge concerning this body been sufficient to enable us to state positively, that an affirmative reply should be given to the question with which this section commences. The experiments of Schönbein and other German observers, of Professor Andrews, which have been confirmed and extended by the author, endorsing as they do the prior researches of Houzeau, now place the matter beyond a doubt.

DOES THE ATMOSPHERE CONTAIN ANTOZONE, *ALIAS* THE PEROXIDE OF HYDROGEN?

We have already seen that Antozone has been proved by certain German savants to be, without doubt, the Peroxide of Hydrogen diffused through a large amount of air.

This body, discovered in 1818 by Thenard, has been supposed by him and by others to be occasionally present in the air.

Dr. Prout.

In 1834 Dr. Prout expressed his belief[1] that "the *excess* of Oxygen above the amount of 20 per cent which there ought to be in the atmosphere, if its composition were, as there can be little doubt that it is, determined by the laws of chemical proportions, becomes associated with the vapour of the atmosphere and forms a Deutoxide of Hydrogen."

M. Dumas.

Schönbein found that in the various processes by which Ozone is artificially formed, whether it be by means of Phosphorus, Ether, or the electrolysis of acidulated and saline solutions, small quantities of the Peroxide of Hydrogen are also produced.[2] Dumas has, moreover, shown[3] that the Peroxide of Hydrogen originates as a result of a great number of chemical reactions, especially the slow combustion of different mineral and organic matters. He has also pointed out that its

[1] *Bridgewater Treatise*, pp. 342, 343; and 569, 570 of the Appendix.

[2] *Ann. de Chemie*, III. lviii. 479.

[3] "Allocution sur les développements qu'ont reçus quelques-unes des principales découvertes de Thenard"—*Compte Rendu de la séance annuelle de la Société de secours des Amis des Sciences*, 1861.

presence in the atmosphere, or on the surfaces of leaves, is not only possible, but even probable. A series of experiments, performed several years since at Kazan, in the interior of Russia, have undoubtedly proved the presence of Peroxide of Hydrogen in snow-water.

Russian experiments.

M. Struve.

Professor H. Struve[1] has informed the French Academy that he has detected the presence of this body in the air. The chief results of his experiments are—

1. Peroxide of Hydrogen is formed in air simultaneously with Ozone and Nitrate of Ammonia, and is condensed in rain water.

2. Peroxide of Hydrogen decomposes a solution of Iodide of Potassium with the separation of free Iodine, only in the presence of free Carbonic Acid.

3. The change which the Iodized Starch paper undergoes, when exposed to the air, is due to the joint action of Ozone and Peroxide of Hydrogen.

MM. Fremy, Schönbein, Meissner, and Gorup-Besanez.

Peroxide of Hydrogen has also been declared to be present in the atmosphere by MM. Fremy, Schönbein, Meissner, and Gorup-Besanez.

Test.

A Sulphate of Manganese paper, which has been coloured by Ozone, has been employed as a test for Peroxide of Hydrogen which decolorizes it. It is not generally applicable, however, for the recognition of this compound in the air, because Sulphurous Acid, even in minute quantity, has a similar effect. Struve states that the best and most effective re-agent for the detection of small traces of the Peroxide of Hydrogen is Oxide of Lead, which becomes converted under its influence into the puce-coloured Peroxide of Lead.

[1] *Comptes Rendus*, 1869.

WHEN

IS OZONE OBSERVED IN THE ATMOSPHERE?

WHEN

IS OZONE OBSERVED IN THE ATMOSPHERE?

THIS question will be considered under two heads:—

1. When has Ozone been observed in the atmosphere?
2. When should Ozone be observed in the atmosphere?

1. WHEN HAS OZONE BEEN OBSERVED?

Ozone is thought by most persons to be an almost constant ingredient of the atmosphere, but to be ever varying in its amount. Mr. Lowe believes, and his opinion is based on a careful consideration of several thousands of experiments, that Ozone is always present in the air. He writes, "On no occasion has my sensitive powder test failed to show traces of it, even at a time when the ordinary test-slips have remained for days uncoloured." Mr. Smyth jun., of Banbridge, who has employed aspirators in the estimation of atmospheric Ozone, states that the variation in its amount is inappreciable. Mr. Buchan, the secretary of the Scottish Meteorological Society, and his staff of Ozone observers, consider it to be "an element of most fluctuating quantity." Ozone is found in very small quantities whilst Northerly winds prevail, and at times when the atmosphere is much contaminated with oxidizable emanations, putrid or otherwise, disengaged from decomposing animal and vegetable substances. A moist and calm state of the weather accompanied by a minimum of Ozone, has been considered to lead to the development of fever, in consequence of the accumulation of the products of decomposition and fermentation. The air in this meteorological state becomes contaminated with an excessive amount of poisonous substances, not only on

Variation or non-variation in amount.

The "moist calm."

account of the absence of all movement of this medium, but from the want of sufficient Ozone to oxidize them, or to render them innocuous. On the accession of an ozoniferous current, a mitigation in the intensity of such a fever and its gradual extinction have been noted.

Influence of the Seasons on the Manifestation of Ozone.

More abundant in winter than in summer.

The majority of observers state that it is more abundant in winter than in summer, whilst a few affirm that it is slightly in excess during the latter season. Its comparative scarcity during the summer has been accounted for, by supposing that more of it is consumed in oxidizing the organic impurities of the air, which are, of course, more abundant during hot weather. Others have believed that less Ozone is produced in summer, in consequence of the occurrence of only one maximum of atmospheric electricity in the twenty-four hours during that period of the year.

Bérigny of Versailles.

Bérigny supplies us with the following relative values of the amount of Ozone in the air of Versailles:—

Summer	45°·318
Winter	38°·983
Difference in favour of summer	26°·335

The close proximity of extensive woods is doubtless concerned in this exceptional result.

Boeckel of Strasburg.

Dr. T. Boeckel of Strasburg shows[1] in the subjoined table that the spring season exhibits the maximum of Ozone in that city.

TABLE 4.

MEAN of OBSERVATIONS extending from 1854 to 1864 = 11 Years.

MEAN.	WINTER.	SPRING.	SUMMER.	AUTUMN.	ANNUAL MEAN.
Morning .	5·26	5·57	4·59	4·05	4·87
Evening .	2·69	5·04	4·79	3·12	3·91
Mean . .	3·97	5·31	4·69	3·58	4·39

[1] "De l'Ozone comme Élément Météorologique," in *Annales de Chimie et de Physique*, October 1865.

Moffat.

Moffat believes Ozone to be greater in the winter and spring months than in summer and autumn.

Scoutetten's opinion.

Scoutetten thinks that the preponderance of Ozone in winter is apparent only, and that this body is produced in smaller amount during the cold and wet season than during the warm and dry, but that the loss is less considerable. In summer, the Ozone is, in his opinion, raised by the heat with the aqueous vapour to the higher regions of the atmosphere, in conjunction with the electricity which accumulates in these elevated positions giving rise to thunderstorms.

Observations at Rouen.

As the amount of Ozone prevalent has never yet been correctly estimated, the above statements, as well as those which will follow, must be regarded as applying to the *purifying principles* contained in the air, and as approximations to the truth, rather than as the truth. The Rouen observations, which approach most closely to accuracy, made, as they are, with tests influenced only by Ozone, represent the spring as the season when Ozone is manifest in maximum quantity, and autumn as that when a minimum is noticed.

	1861-1864. Means of the Seasons.
Winter.—January, February, March .	22
Spring.—April, May, June . .	56
Summer.—July, August, September .	37
Autumn.—October, November, December	19

It would seem as if vegetable activity and decay also exercised a determining influence on the proportion found in the air at *this* station. Houzeau divides the year in our climates into two great divisions:—the *very active season* (spring and summer), when the chemical activity of the air is greatest; and the *slightly active season* (autumn and winter).

Maximum and minimum months.

There is some diversity of opinion among observers as to the particular months of the year characterized by the manifestation of the maximum and minimum amounts of Ozone. Let us collect the reports of a few of the stations

that are separated from one another by the greatest distances, and endeavour to settle this question.

TABLE 5.

Station.	Maximum.	Minimum.
Prague	July and August.	October.
Vienna	February.	September.
Kremsmünster . . .	February.	July.
Banbridge, Ireland .	December.	July and August.
Eccles, near Manchester	March and April.	November.
Salzburg	February.	November and December.
Versailles	May.	November.
Rouen	May and June.	January.
Scotland	May.	November.
Kœnigsberg . . .	March.	November.
Toronto	March.	April.
Isle of Islay . . .	February and May.	October.
Whitby (Lighthouse near)	April.	November.
Shetland	February.	November.
Culloden	April.	August.
Isle of Lewis . . .	March.	July.
Faroë Isles	July and September.	April.

In the absence of any conclusive evidence, it will be desirable to examine the larger Table 17, on page 97. The majority of the stations therein contained show a maximum amount of Ozone in February and May, and a minimum during the months of November and July.

Prestel.

Dr. Prestel informs us[1] that the maxima are noticed at the time of the equinoxes, that of the spring equinox being larger than that at the autumnal; and that the minima occur just before the solstices, the larger one being a short time before the winter solstice, and the lesser one a little in advance of the summer solstice. Reslhuber states that, at Kremsmünster, the months which exhibit the maximum and minimum amounts of Ozone are generally distinguished by the following opposite climatic conditions:—

[1] "Die Jährliche periodische Aenderung des atmosphärischen Ozons und die Ozonoskopische Windrose als Ergebniss Beobachtungen zu Emden:" Dresden, 1865.

Characteristics of maximum and minimum months at Kremsmünster.

February Maximum.	July Minimum.
Temperature—Low . .	Warm.
Barometric Pressure—Low .	Mean amount.
Clouds—chiefly Cirro-Strati .	Chiefly Cumuli.
Degree of Humidity—Damp .	Driest month of the year.
Dull, overcast . . .	Bright and clear.
Good deal of snow . .	Thunderstorms.

Diurnal and Nocturnal variations in the amount of Ozone.

The question, as to whether or not Ozone is more abundant during the night than by day, has been answered in the affirmative by some and in the negative by others. It is desirable to ascertain the truth, as to the relative amount during the hours of light and darkness, in order to be in possession of data for the study of the all-important subject of the production of Ozone. That the dispute may be for ever set at rest, let us examine the day and night observations at several stations.

TABLE 6.

Amount of Ozone during the Day and Night.

Months.	Emden. 1857-1863.		Prague. 1854-1857.		Kremsmünster. 1855.		Kirchdorf. 1855.		Isle of Islay, Scotland. 1870.		Nancy. 1854.		Strasburg. 1854-1864.	
	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.
January .	4·90	6·90	·33	·94	6·21	6·52	6·26	7·40	7·75	8·66	2·80	5·30	2·89	5·52
February	5·91	6·93	·73	1·55	7·70	7·98	7·96	8.50	7·90	8·76	5·30	6·80	2·80	5·38
March .	7·75	7·82	1·03	1·79	5·91	6·50	5·90	6·52	7·25	8·94	t5·30	3·80	4·49	5·28
April . .	t7·50	7·34	1·24	1·47	5·83	6·34	5·36	6·05	7·40	8·24	t8·10	4·80	5·00	5·50
May . .	6·54	6·57	1·51	1·72	4·16	5·98	4·47	5·68	8·20	8·41	t7·90	7·40	5·63	5·95
June . .	t6·40	5·93	1·90	1·93	2·70	3·66	3·20	4·07	7·17	8·24	t7·90	7·30	t5·24	5·18
July . .	t5·93	5·23	t2·25	1·83	2·27	3·36	2·64	3·70	7·62	7·92	t7·30	5·90	t4·66	4·43
August .	t6·55	5·25	1·83	2·17	t3·05	2·94	3·05	3·55	6·73	8·07	t7·50	4·50	t4·47	4·30
September	t6·71	5·64	1·05	1·16	t4·41	4·32	t3·85	2·88	7·17	8·10	t5·60	2·60	t4·52	4·40
October .	t6·14	5·38	·39	·74	t4·42	4·29	3·58	3·63	t7·61	7·16	t5·10	3·70	2·62	3·51
November	4·07	5·48	·54	1·06	5·26	5.67	4·21	4·65	8·00	8·16	3·30	5·30	2·16	4·21
December	5·07	6·80	1·15	1·96	6·23	6·43	6·20	6·26	7·85	7·92	4·22	6·20	2·36	4·88
Mean .	6·12	6·27	1·16	1·53	4·85	5·40	4·77	5·15	7·55	8·21	5·86	5·30	3·90	4·88

The observations of Dr. Prestel have convinced him that, at Emden, there is less Ozone by day than at night Emden.

[t] Months during which the day exceeded the night mean.

in the winter half of the year, from November to April; whilst it is more abundant during the former than during the latter period of the twenty-four hours in the summer. He finds also, that the differences between the degree of ozonic reaction in the day time and during the night are much greater in winter than in summer. (*Vide* Table 7.)

When we remember the position of Emden on the northern coast of Germany, the preponderance of Ozone during the days of summer is easily explained. Emden enjoys, on the afternoon of every clear warm day during that season of the year, a sea breeze which is richer in Ozone than any land breeze.

Nancy and Strasburg.

At Nancy and at Strasburg, the larger amount of Ozone during the day than at night, in the summer months, cannot be so easily comprehended. The test papers at these stations may have been accidentally influenced by the light during the very long days of this season. All the other stations exhibit, during the greater part of the year, a deeper Ozonic reaction at night.

Algeria.

Observations made in warmer climates, such as that of Algeria, indicate a similar result.[1]

Mean of Observations in 1855 at 7 a.m. and 5 p.m.

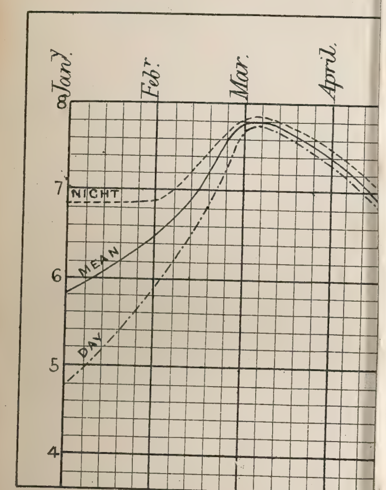
October.		November.		December.	
Day.	Night.	Day.	Night.	Day.	Night.
5·5	7·5	5·1	6·1	5·5	5·9

Berne.

M. Wolf finds that, at Berne, the coloration of the tests during the night is always more feeble than during the day, and that the difference is most apparent in the winter season.

[1] *Gazette Medicale d'Alger.*, No. 1, January 1856.

of the difference
Ozonic Reacti



Metz.

In the open country.

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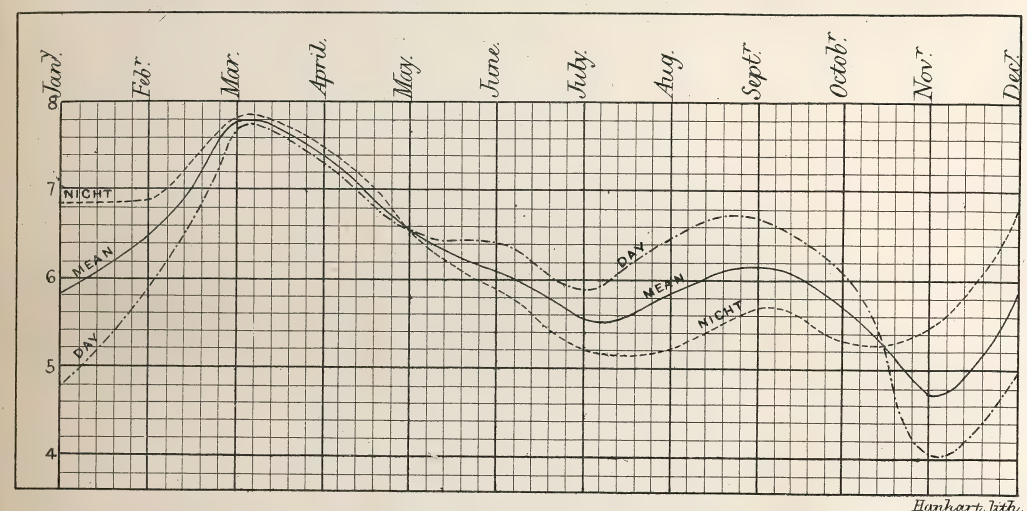
[1] *Gazette Medicale d'Alger.*, No. 1, January 1856.

TABLE 7.

Graphical Delineation
of the difference between and the amount of Day and Night
Ozonic Reaction during the various Months of the Years
1857 - 1863.



Nancy and Strasburg.

Algeria.

Berne.

TABLE 8.

Ozone by Day and Night at Berne.	Mean of the Nights.	Mean of the Days.	Difference in favour of the Days.
1853.			
Spring (March-May) . .	6·43	6·47	0·04
Summer (June-August . .	3·47	3·57	0·10
Autumn (September-November . .	2·50	3·20	0·70
Winter (December-February .	4·97	5·57	0·60
1854.			
Spring	4·97	5·17	0·20
Summer	3·73	4·37	0·64
Autumn	3·10	4·37	1·27
Winter	5·10	6·00	0·90

Scoutetten states that, at Metz, the tests are nearly always found to be of deeper tints during nights than days, and that the reverse only occurred five times during the seven months from October 1855 to the end of April 1856. With the object of ascertaining whether such is the case in the open country far away from all human habitations, he selected a little mountain, distant from every cause of insalubrity, as a place of observation, and compared the results with those obtained on the Metz cathedral. His conclusions are here transcribed:— Metz. In the open country.

1. With a cloudless and calm sky, Ozone reacts on the tests more strongly by night than by day, whatever the temperature may be.

2. Certain meteorological phenomena may disturb this law—such, for instance, as the change of the wind from the North to the South-East, a storm, or a fall of snow.

3. It is not rare to note more Ozone (test reaction?) in a town by day than at night; whilst the contrary is exhibited in the open country, or on a very high monument, during the same day and during the prevalence of the same atmospheric conditions.

Schiefferdecker.

Schiefferdecker states that six-sevenths of night observations exceed those made during the day, and that the difference is least in winter, greater in summer, and greatest in spring and autumn.

Lowe.

Mr. Lowe of the Beeston Observatory also found that the excess of Ozone at night over that of the day varies during the different seasons of the year.[1]

In December and January an excess at night over the day of			0·8.
February and March	"	"	0·7.
April and May	"	"	0·7.
June and July	"	"	0·1.
August and September	"	"	0·4.
October and November	"	"	0·5.

The excess of test coloration at night over that of the day is here seen to be double as much during the winter as during the summer months.

Rogers.

Professor W. B. Rogers has also published[2] a table illustrative of the comparative energy of the ozonic reaction at night over that at the day time during five months of the year 1856.

In June—Ratio of night to day		. .	100·84
July	"	" . .	100·87
August	"	" . .	100·89½
September	"	" . .	100·82
October	"	" . .	100·83

Influence of sun's hour-angle on the production of Ozone.

With the object of throwing light on the cause of the formation of atmospheric Ozone, and of the variations in the amount which is developed, the influence of the sun's hour-angle on the production of this body was studied at Greenwich from August 31, 1856 to December 31, 1867;[3] and by Mr. Cann Lippincott at Overcourt, near Bristol, from August 31 to December 31, 1856, and during the

[1] *Brit. Assoc. Rep.*, 1862.

[2] "On Ozone Observations," *Edinburgh New Philosophical Journal*, January 1858.

[3] *Greenwich Observations*, 1856, pp. clxvi.-clxxxii.; 1857, pp. clxvi.-ccx.

whole of 1857, by making hourly observations once a week. This gentleman found the mean amount of Ozone for each of these twenty-four hours to be, during the year 1857—

Hourly observations every week.

Ozone.	Hour.		Ozone.	Hour.	
1·84 . .	12 midnight.		·80 . .	12 noon	Min.
2·15 . .	1 A.M.		·96 . .	1 P.M.	
2·33 . .	2 "		1·17 . .	2 "	
2·70 . .	3 "		1·31 . .	3 "	
3·13 . .	4 "		1·41 . .	4 "	
3·62 . .	5 "		1·33 . .	5 "	
4·11 . .	6 "	1st Max.	1·33 . .	6 "	
4·60 . .	7 "		1·41 . .	7 "	
4·88 . .	8 "		1·56 . .	8 "	2d Max.
4·45 . .	9 "		1·70 . .	9 "	
·31 . .	10 "	Min.	1·00 . .	10 "	
·41 . .	11 "		1·05 . .	11 "	

The results of the observations during the portion of the year 1856 agree with those of the year 1857, which may thus be summarized—

1. A well-marked period of *maximum* development of Ozone occurs between 4 and 9 A.M., and an equally well-marked period of *minimum* development between 10 A.M. and 1 P.M.

3. There is a tendency to a second period of *maximum* development between 7 P.M. and 9 P.M., and to a second period of *minimum* development between 10 P.M. and midnight.

3. That the amount of Ozone developed between midnight and 9 A.M. is considerably greater than that developed between 10 A.M. and 11 P.M.

Mr. Lippincott arrives at the following deductions:—[1]

(*a.*) "That the *maximum* development of Ozone takes place when the sun is near the *eastern horizon;* and that there is a tendency to a second *maximum* when the sun is near the *western horizon:* and,

[1] *Proc. Meteor. Soc.*, vol. iv. No. 37

(*b.*) "That the *minimum* development of Ozone occurs when the sun is near the zenith; and that there is a tendency to a second *minimum* when the sun is near the *nadir*."

Hourly observations every day.

The hourly observations made by him in 1869, which differ from those already referred to in the fact that they were made daily instead of weekly, also display the *mid-day minimum* and the maxima at sunrise and sunset. They do *not*, however, show the existence of a *minimum when the sun is near the nadir;* but, on the contrary, they indicate a very decided excess.

TABLE[1] 9.

MEAN HOURLY AMOUNTS of OZONE on the Averages of the Months from the 20th of February to the 18th of November inclusive, deduced from Observations taken at Over Court, 6-7 miles from Bristol, in the Year 1869. Height of Ozonometer above the sea 148 feet. Lat. 51° 32′·5 N., long. 2° 34′ W.

Test-paper, Schönbein's. Scale 0 to 10.

1869. Months.	Hours.—Morning.												
	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	
	12	13	14	15	16	17	18	19	20	21	22	23	
Feb. 20 to end	2·5	2·5	2·3	2·3	2·1	2·1	2·0	1·7	2·0	1·8	1·1	1·6	...
March . . .	2·8	3·0	2·7	2·4	2·6	2·7	2·6	2·7	2·3	1·9	1·7	2·1	...
April . . .	3·0	3·2	3·3	3·2	3·1	3·3	3·3	3·2	2·9	2·4	1·7	2·3	...
May . . .	3·2	3·3	3·5	3·4	3·2	3·2	3·1	3·2	3·2	2·9	2·5	2·7	...
June . . .	1·3	1·3	1·2	1·2	1·4	1·6	1·7	1·7	1·5	1·6	1·2	1·3	...
July . . .	2·2	2·3	2·4	2·3	2·4	2·6	2·7	2·5	2·4	2·4	1·6	1·8	...
August . . .	2·2	2·2	2·4	2·2	1·7	1·9	2·0	2·1	2·1	2·0	1·5	1·6	...
September . .	4·6	4·5	4·5	4·4	4·4	4·6	4·7	4·6	4·5	4·2	3·5	3·4	...
October . .	2·2	2·3	2·2	2·2	2·1	2·3	2·4	2·4	2·1	1·9	1·7	1·6	...
November 18 .	3·7	3·8	3·5	3·7	3·7	3·8	3·7	4·1	3·6	3·2	3·2	3·2	...
Means . .	2·8	2·8	2·8	2·7	2·7	2·8	2·8	2·8	2·7	2·4	2·0	2·2	...

[1] *Proceed. of Meteor. Soc.*, vol. v. No. 46.

Mean Hourly Amounts of Ozone—*Continued.*

	Hours.—Afternoon.												Means.
	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	
	0	1	2	3	4	5	6	7	8	9	10	11	
Feb. 20 to end	2·1	2·1	2·0	2·4	2·1	2·3	2·3	2·2	2·1	2·1	2·5	2·7	2·1
March . . .	2·5	2·6	2·6	2·7	2·7	2·8	2·7	2·5	2·1	2·3	2·6	2·5	2·5
April . . .	2·8	3·1	3·1	3·2	3·4	3·5	3·4	3·3	3·2	3·0	2·7	2·9	3·0
May . . .	2·9	3·0	3·0	3·1	3·1	3·3	3·4	3·2	2·9	2·8	3·0	3·1	3·1
June . . .	1·5	1·5	1·6	1·7	1·8	2·0	1·9	1·7	1·6	1·5	1·5	1·5	1·5
July . . .	2·0	2·1	2·2	2·4	2·7	3·1	3·0	2·8	2·5	2·4	2·5	2·5	2·4
August . .	1·7	1·8	2·0	2·2	2·2	2·1	2·0	2·0	2·1	2·0	1·9	2·0	2·0
September .	3·8	3·8	3·8	3·9	4·0	4·3	4·2	4·2	4·1	4·4	4·6	4·8	4·2
October to .	1·5	1·4	1·4	1·6	1·8	1·9	1·6	1·6	1·7	1·7	1·8	1·9	1·9
November 18 .	3·1	2·8	3·3	3·4	3·5	3·5	3·5	3·3	3·1	3·6	3·8	4·0	3·5
Means . .	2·4	2·4	2·5	2·7	2·7	2·9	2·8	2·7	2·5	2·6	2·7	2·8	2·63

The experience of Osann enables him also to state that the ozonic reaction is strongest towards sunrise, when the atmospheric moisture is precipitated. That the largest maximum should be observed at this period of the twenty-four hours is not surprising. The contamination of the air, of course, chiefly occurs during the day. When a condensation of aqueous vapour takes place at its close, the organic and other impurities are carried down to the earth. The air being thus washed, a maximum of Ozone is then noted. At the precipitation about sunrise, the atmosphere is still further purified by a repetition of the cleansing process, when the highest maximum of Ozone is registered. The experiments of M. Morin and others, with respect to the production of Electricity and Ozone by the pulverization of water, render it extremely probable that these aqueous precipitations are, moreover, themselves attended by the development of Ozone. Osann.

The observations contained in the foregoing Table prove that the amount of Ozone in the air not only undergoes a monthly, but a daily and even hourly variation.

The two series of hourly observations show con-

clusively that a greater amount of Ozone is present during the night than by day. If the hours between 9 A.M. and 9 P.M. be considered as constituting the day, and those between 9 P.M. and 9 A.M. as forming the night, we obtain these figures:—Day, 1·83. Night, 2·86.

Influence of certain Atmospheric States and Phenomena on the production of Ozone.

(*a*) Electricity, Thunderstorms, Halos, and Auroræ.

ELECTRICITY.

The diurnal and nocturnal as well as the monthly variations in the intensity of Electricity have been thought by some to be synchronous with those of Ozone. The investigations of Mons. Quetelet of Brussels would seem to lend some countenance to this supposition. The existence of a connection is rendered more probable, when they are compared with the hourly ozonometric researches of Mr. Lippincott, which have just been described. The following observations were made by means of Peltier's electrometer in August 1842.

Hourly electrical and ozonometrical observations.

TABLE 10.

Hours.	Electrometer.	Ozone.
6 a.m.	+ 17°	4·11
7 "	27	4·60
8 "	36 max.	4·88 max.
9 "	27	4·45
10 "	20	·31
11 "	14	·41 min.
12 "	12	·80
1 p.m.	10	·96
2 "	5	1·17
3 "	3 min.	1·31
4 "	5	1·41
5 "	11	1·33
6 "	18	1·33
7 "	24	1·41
8 "	30	1·56
9 "	32 max.	1·70 max.
10 "	30	1·00
11 "	19	1·05

The variations in the quantity of Electricity and of Ozone in the air are, probably, to a great extent influenced by the same causes which are concerned in the production of the diurnal fluctuations of the pressure of the air, namely, changes of its temperature and of its quantity of aqueous vapour.

An examination of observations as to the relative amount of atmospheric Electricity during the several months of the year, at different stations, displays an agreement in assigning the maximum to the months of December, January, and February, and a minimum to the hot summer months.

Monthly electrical observations at different stations.

TABLE 11.

Months.	BRUSSELS by Quetelet.[1] 1845-1853. Peltier's Electrometer.	MUNICH by Lamont.[2] 1850-1853. Lamont's Electrometer.	KEW, SURREY.	GAND by Duprez. 1855-1863. Peltier's Electrometer.
	Degs.	Degs.	Degs.	Degs.
January	+ 48	+ 5·93	+ 182·4	+ 18
February	+ 44	+ 5·94	+ 179·3	14
March	34	5·55	58·2	8
April	25	4·01	40·7	6
May	19	3·26	41·3	3
June	− 17	− 3·09	26·8	4
July	− 17	− 3·14	31·8	4
August	21	3·29	− 28·5	4
September	25	3·18	31·0	6
October	32	4·10	65·1	11
November	41	5·28	80·5	17
December	+ 47	+ 6·46	+ 126·3	16

M. Quetelet states that, when there is a cloudless sky and dry weather, there are almost always powerful indications of Electricity if the observation is made in winter,

[1] "Observations des Phénomènes Périodiques," extracted from *Mémoires de l'Academie Royale de Belgique*, vol. xxix.

[2] "Entnommen aus dem Jahresberichte der Münchner Sternwarte, pag. 72, und aus dem vii. Bande der Annalen der K. Sternwarte zu Bogenhausen bei München."

and very feeble ones if made in summer. He gives the following arrangement in his work, *Meteorologie de la Belgique comparée à celle du Globe,* which not only indicates the influence of moisture, but that of temperature, on the development or manifestation of atmospheric Electricity.

The coldest or Winter months.

1. Maximum of Electricity; normal Humidity—cloudless sky.
2. Minimum of Electricity; normal Humidity—overcast sky.
3. Maximum of Humidity; much Electricity—slight fog.
4. Minimum of Humidity; much Electricity—cloudless sky.

Hot and temperate or Spring, Summer and Autumn months.

1. Maximum of Electricity; slight amount of Humidity—dry and cloudy weather.
2. Minimum of Electricity; slight amount of Humidity—dry and cloudless weather.
3. Maximum of Humidity; slight amount of Electricity—damp and overcast weather.
4. Minimum of Humidity; slight amount of Electricity—very dry and cloudless weather.

Lamont says, that "the variations of electrical tension on the surface of the ground depend exclusively upon the aqueous vapour present in the air;" whilst Reslhuber thinks that, "according to the conditions of vapour and moisture, the changes in the amount of Ozone in the atmosphere are also dependent."

Influence of the temperature of the air on the manifestation of Electricity and Ozone.

The temperature of the air would appear to exert as great an influence as its humidity, if not a greater, on the development of atmospheric electricity and on the indications of ozonoscopes. Overlooking the effects of temperature, some have considered that the humidity of the air is solely concerned in the production of the early

morning and evening maxima. The diminution in the intensity of Electricity and in the amount of Ozone about the middle of the day, has been ascribed to the dryness of the air. It has hitherto been considered to be impossible to reconcile the facts that Electricity is more powerful and Ozone more abundant, whilst the air is drier and colder, as we ascend into the atmosphere. The key to the mystery is to be found in the changes of temperature. It must not be forgotten that a crowd of local influences interfere with the manifestation of Electricity and of ozonic reaction on the surface of the earth, from which the higher strata of the atmosphere are exempt.

Electricity.		Ozone.	
More.	Less.	More.	Less.
In winter.	In summer.	In winter.	In summer.
With a moderate amount of moisture.	With a dry air.	With a moderate amount of moisture.	With a dry air.
With low temperatures.	With high temperatures.	With low temperatures.	With high temperatures.
At commencement and end of day.	At mid-day.	At commencement and end of day.	At mid-day.
In elevated localities.	At earth's surface.	In elevated localities.	At surface of earth.

Decharmes and others state that the development of Ozone follows the same progression as that of atmospheric Electricity, "the curves which represent graphically the march of these two elements being nearly parallel."

Saussure has asserted that fogs give rise to a marked development of Electricity. Quetelet has observed a maximum in *cold,* foggy weather. Kœmtz writes:[1]—"Accord- Fogs, Electricity, and Ozone.

[1] *Cours Complet de Météorologie.*

ing to my experience at Halle, I am inclined to believe that Electricity is more feeble during a fog than during fine weather. On the Alps, I have always found in fine weather a strong positive Electricity; but, if clouds approached, its intensity diminished, and it was almost *nil* when I was enveloped in clouds." Further researches seem to be required to settle this question. As ozonoscopes generally exhibit a minimum of coloration during the foggy month of November, it is one of some interest. The vaporization of the Iodide of Starch, in consequence of the contact of moisture, may possibly be the cause of the exceedingly low mean which is so commonly attached to this month. The friction of the minute vesicles of water composing fogs against one another, which must necessarily occur, would lead one *a priori* to infer that such condensations would be always electrical.

THUNDERSTORMS.

Boehm's observations at Prague seem to show that the majority of thunderstorms are accompanied by a simultaneous increase in the depth of the colour of tests. Out of seventeen of these electrical phenomena noted by him, five were signalized by the absence of even the slightest tint. During the occurrence of these five the wind was either N. or S., whilst the remaining twelve happened when the wind blew from the W. The observers of Königsberg noticed, that of the six thunderstorms which visited them during June, August, and September 1852, two only were accompanied by a considerable augmentation in the amount of Ozone; and that this increase did not take place on the same day, but on the day after the storm. Scoutetten explains this fact by supposing that a certain time is necessary for the cooling down of the air, and for the condensation of aqueous vapour and its descent to the earth. He points out that, if thunderstorms are attended by little or no rain, there is very feeble ozonic reaction. Reslhuber also, who has especially studied the manifestations of Ozone in relation to atmospheric conditions, states, that "with thunderstorms, the amount of Ozone is dependent upon the amount

and kind of the aqueous precipitations which accompany them." Dr. Moffat having ascertained that his ozonometric observations, made during the last twenty years, yield a mean daily quantity of 2·3, found (1) that it is equal to the mean daily amount with halos, auroræ, and the zodiacal light, but below it with thunder and lightning; and (2) that with all these phenomena, Ozone is often in maximum quantity, its presence or absence depending on the state of the barometer when they occur. If the barometric readings be *in*creasing, Ozone will be absent or in minimum quantity; but, if *de*creasing when they appear, Ozone will be present and in maximum quantity.

HALOS, AURORÆ, etc.

WHEN BAROMETER IS FALLING.

Thunder.	Thunder and Lightning.	Lightning.	Aurora.	Solar Halo.	Lunar Halo.	Fog.	Hail.	Snow.	Sleet.
2·0	2·1	2·8	2·8	1·9	2·6	0·2	3·1	1·9	2·8

WHEN BAROMETER IS RISING.

1·0	0·9	1·0	0·9	0·8	...	0·0	1·2	0·8	0·0

My own observations at Scarborough have not exhibited an increased amount of test-coloration, either during thunderstorms or auroral displays.

It is said that cloth goods will not dye when Ozone is absent from the air; and we learn that the effect of a thunderstorm in increasing the power of the mordant is remarkable. Dyeing.

Dust storms, which are generally regarded as electrical phenomena, have been found in India to be attended, like thunderstorms, by an increased coloration of tests, although not to so marked an extent. Dust storms.

(*b*) Rain, snow, hail, fog.

The preceding table appears to indicate that the pressure of the air exercises no insignificant influence, also,

on the amount of Ozone developed during *these* atmospheric phenomena.

Rain and Snow.

Houzeau has found that Ozone is more frequently present in the air during days of rain than during days of fine weather. It was detected

On 38 out of 100 days of rain, and
„ 28 „ 100 „ fine weather.

Schönbein informs us that the falling of snow is attended by a very strong ozonic reaction, which he attributes to an electrical disturbance in the air that is said to have its principal cause in the breaking up of the snow-flakes. Wolf gives the following relative proportion of test-coloration during fine, rainy, and snowy days:—

Fine days	4.86
Rainy	11.40
Snowy	14.15

Königsberg

Schiefferdecker and his coadjutors found the following amounts of Ozone at Königsberg during the year from June 1852 to May 1853:—

TABLE 12.

Scale of 20 degrees employed.

Mean Amount of Ozone during Fine, Rainy, and Snowy Days.

Months.	Days.			Mean amount of Ozone during Days.		
	Fine.	Rainy.	Snowy.	Fine.	Rainy.	Snowy.
June . . .	12	18	...	4·6	6·2	
July . . .	22	9	...	4·5	6·0	
August . . .	16	15	...	4·6	6·6	
September . .	12	18	...	3·4	10·0	
October . . .	2	26	3	5·4	8·3	9·0
November . . .	3	20	7	7·8	7·1	8·8
December . . .	2	23	6	7·2	8·8	11·3
January . .	14	11	6	7·6	10·0	9·7
February . . .	10	3	15	10·7	11·8	10·9
March . . .	18	7	6	11·1	12·9	11·0
April . . .	13	18	6	10·0	11·2	10·6
May . . .	6	18	...	7·0	8·3	...
Mean . .	130	186	49	6·9	8·9	10·1

Kremsmünster.

The relative amount of Ozone at Kremsmünster in 1855, during the precipitation of water in the several forms which it assumes under the influence of temperature, electricity, etc., was carefully determined by Reslhuber by means of observations two hours in duration.

	Ozone. (Schönbein's Test.)	Number of observations.
Rain, ordinary . . .	3·82	51
„ heavy, continuous .	5·33	15
Snow, ordinary . . .	4·42	42
„ in the form of icicles .	5·00	16
Hail and Sleet . . .	6·38	4
Fog—no wind . . .	·85	12
„ gentle breeze . .	3·55	10
„ with icicles . .	4·00	5

Hail and Fog.

Scoutetten finds that the occurrence of snow and hail constantly coincides with an augmentation in the amount of atmospheric Ozone, and that rain and fogs determine different effects, according to their conditions of production. If rain follows a storm, and returns after a temporary reappearance of blue sky, the test-paper exhibits deep tints. If, on the contrary, the rain is fine and continuous, and the temperature is slightly elevated, there is little Ozone. With dense fogs, when the air is saturated with moisture, he has found the ozonoscope indicate 0, but exhibit a blue tint on its disappearance. If the fog is dry and is rapidly dissipated, entirely opposite results are furnished.

Formation of fog and drizzle.

Dr. Moffat considers that fog and drizzle are formed in two ways:—When the readings of the barometer are *in*creasing, and a gentle polar current passes over a moist soil which is warmer than the air, fog is formed without Ozone; but, if the barometric readings are *de*creasing, and an equatorial current is approaching that is warmer than the soil, fog is formed with Ozone the amount of which is often great. He adds, "It is owing to the latter conditions, that we often see Ozone with dense fogs at the commencement of thaws, especially when the ground is covered with snow. I have often found the tests perfectly colourless with fog and drizzle under the former

conditions, whilst they have been as high as 9° with the latter."

The coloration of ozonoscopes is said to be so intense during a fall of snow, that each flake falling upon a test-paper produces a blue stain. I have several times exposed the *purest* and most sensitive tests to falling snow, but have not observed this effect.

Causes of increased ozonic reaction after aqueous precipitations.

The increase in the amount of Ozone after rain may probably be ascribed to (1) The washing out of the air of the impurities continually passing into it, in the oxidation of which the Ozone was previously consumed; and (2) The production of Electricity. As the descent of water through the air is known to give rise to negative Electricity, this modification of Oxygen is doubtless at the same time developed.

(*c*) Wind.

WIND.

A fixed relation has been almost universally acknowledged to exist between the direction of the aerial current and the intensity of the coloration of Iodized Starch paper. Most observers have found that the humid equatorial winds, which are so frequently accompanied by rain, rapidly discolour the tests, whilst cold polar blasts affect them languidly. The simple Iodide of Potassium ozonoscopes seem to be most powerfully influenced by cold and dry winds, with the exception of those from the North.

Dr. Moffat's observations.

Dr. Moffat has traced[1] a connection between Ozone periods and the luminosity of Phosphorus, and between no Ozone periods and the non-luminosity of this metalloid. He has constructed tables to show that Ozone is at its maximum, and Phosphorus is most luminous, during the prevalence of atmospheric conditions which characterize the South or equatorial current of air—namely, a minimum of atmospheric pressure and maximum of temperature and humidity; and that Ozone is at its minimum, and Phosphorus is non-luminous, during the meteorological states of the air which accompany the North or polar current—namely, a maximum of pressure and a minimum of temperature and humidity.

[1] *Proc. Meteor. Soc.*, June 18, 1862.

TABLE 13.

Barometer.		Temperature.		Humidity.		Direction of Wind.	
Increasing.	Decreasing.	Increasing.	Decreasing.	Increasing.	Decreasing.	North or Polar Points.	South or Equatorial Points.
Minimum of Ozone.	Maximum of Ozone.	Maximum of Ozone.	Minimum of Ozone.	Maximum of Ozone.	Minimum of Ozone.	Minimum of Ozone.	Maximum of Ozone.
Phosphorus.		Phosphorus.		Phosphorus.		Phosphorus.	
non-luminous.	luminous.	luminous.	non-luminous.	luminous.	non-luminous.	non-luminous.	luminous.
29·698. Mean.	29·555 Mean.	50°·3 Mean.	45°·0 Mean.	83·9 Mean.	81·2 Mean.	Phosphorus luminous 5 days in 100.	Phosphorus luminous 41 days in 100.

Boston, America.

Professor Rogers[1] of Boston has stated that as long as the wind blows from E. or S. points, the coloration of Schönbein's test paper is almost or quite *nil;* but whenever the current changes to W. or N.W., a deep tinting is unfailingly indicated.

Torquay.

Dr. Daubeny[2] found at Torquay that Schönbein's tests were most deeply tinted during S.W., W., and S. winds, and were least coloured when N. winds prevail.

1 S.W.; 2 W.; 3 S.; 4 E.; 5 N.W.; 6 N.E.; 7 S.E.; 8 N.

Oxford.

At Oxford, on the other hand, he obtained entirely different results, an E. wind containing most Ozone, and a N.W. wind least.

Nottingham.

Mr. Lowe of the Highfield Observatory has noticed, like most inland observers, that Ozone is apparently most abundant during a S.W. and S.S.W. wind, and least plentiful with a N. or N.E. wind; and that the maximum is attained when the barometer is at its lowest, and the minimum when at its highest readings.

Influences of temperature and degree of moisture of the air.

We know that chemical action increases with an augmentation of heat, and diminishes with the fall of the thermometer. Moisture, too, if moderate in amount, is favourable to chemical action. I quite agree with Mr. Lowe in thinking that these results, which are in harmony with those arrived at by Dr. Moffat and myself, may be to a certain extent attributed to circumstances operating for or against the development of Ozone, such as changes in the temperature and hygrometric condition of the air, at one time increasing, and at another diminishing, its amount.

Sea-side places are visited by a greater quantity of Ozone when winds blow from the sea, which is one of the great manufactories of allotropic Oxygen, than when they proceed from the land.

[1] *Proc. Bost. Soc. Nat. Hist.*, v. 319.

[2] Paper on Ozone read before the Chemical Society, November 15, 1866.

TABLE 14.

Average Amount of Ozone during the prevalence of the various Winds.

Place of Observation.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.	Position of Station with reference to and distance from a Town.	Remarks.
Berne	10·6	9·0	7·10	6·7	8·0	11·4	12·8	10·6	..	....	From *Annalen der Physik und Chemie*, Band xciv. Stück 2, 1855.
Bournemouth	4·1	5·2	5·6	4·0	3·4	4·3	3·8	3·5	..	¾ mile from town.	House detached, situated under pine woods.
Cairndow	6·5	6·9	7·0	7·0	7·6	8·1	7·8	7·7	..	7 miles N.E. of Inverary.	
Dublin	·24	·25	·27	·40	·40	·55	·60	·56	·31	3¾ miles from General Post Office.	Observations taken in Phœnix Park.
Dumfries	67	42	42	32	19	51	51	67	..	....	Number of days are given.
Dunse, Berwick	58·5	49·5	17·5	9·0	9·5	33·5	114	65	8·5	N.W. of Dunse	Dunse, pop. 2556, is 6 miles from station which is well wooded. The relative proportion is given.
East Linton, Haddington	13·5	32·5	40·8	20·2	25·9	130·9	64·7	22·5	14	S. of town, pop. 900.	The relative proportion only.
East Yell, Shetland	5·0	4·0	3·0	9·0	8·0	10·0	7·0	6·0			
Emden	7·8	6·2	5·4	5·2	6·1	7·5	7·8	8·0			
Gloucester	2·9	2·7	4·6	4·9	4·6	2·8	1·7	1·9	..	½ mile from centre.	At the east outskirts of city.
Halifax	58·3	88·0	38·3	25·6	25·3	89	144	176·6	..	2 miles from town.	The figures indicate the relative amount only.
Hawarden	1·3	1·0	1·8	4·2	3·0	5·5	5·0	4·1	..	6 miles to W. of Chester.	Liverpool is 20 miles to the N.E.
Helstone	41	26	67	15	28	78	56	54	..	....	Relative proportion given. Observations made in open space in garden.
Kremsmünster	5·70	4·85	4·64	3·83	2·50	5·26	6·02	5·77	..		
Marlborough	3·2	3·1	2·6	1·8	1·9	3·4	3·7	3·8	4·9	West end of the town.	
Melbourne Observatory	4·5	4·3	4·3	4·3	5·6	7·4	7·5	6·0	..		
Millbrook	7·2	7·0	6·7	7·5	8·0	8·4	8·3	7·5	..	2 miles from a town.	
Nookton	7·2	8·4	8·0	7·2	6·0	4·6	4·3	4·9	..	2 miles W. of a town.	Nookton is near Leven, in Fifeshire.
Osborne, Isle of Wight	4·6	5·4	5·5	5·8	6·8	6·7	5·7	4·6	..	One mile E. of Cowes.	
Oxford	4·4	5·1	4·0	3·6	4·7	4·7	3·7	3·8	..	....	At the Radcliffe Observatory.
Prague	1·22	·63	·45	·57	·73	2·64	3·58	1·62			
Rouen	120	170	84	100	168	166	48	94	..	In suburb.	Number of days are given when tests colour.
Scarborough	3·3	..	3·5	..	3·4	..	3·3	..	..	In suburb, S. of town.	From 1865 to 1866.
Spital, near Carlisle	1½	2	4¼	2½	4	5½	7¼	2½	2¼	1½ mile from centre of Carlisle.	Relative proportion instead of amount given.
Taunton	6·0	4·0	7·5	7·0	3·0	4·16	4·0	3·0	..	½ mile from town.	
Toronto Observatory	1·9	7·6	11·8	3·5	6·0	8·8	2·9	5·6	..	One mile N.N.W. of dense part of city.	
Weybridge Heath, Surrey	2·91	2·47	2·24	2·43	3·08	4·17	4·00	3·19	..	1 mile S.E. of a village.	
Whitby (Lighthouse near)	9·2	9·5	9·0	7·5	8·3	7·3	7·8	8·9	..		

An examination of this Table, which should be studied by readers, shows that, at the majority of the stations, the deepest coloration occurred with W. and S.W. winds, and the least with those proceeding from Northerly and South-Easterly points. *True* Ozone tests appear to colour deeply most frequently during the prevalence of N.E. winds, and least frequently when the wind blows from the West (*vide* Rouen).

In consequence of the preponderance of local influences to which ozonoscopes have been in most places subjected, by reason of their proximity either to the sea, to woods, to towns, or to manufactories, etc., they indicate the relative amount of active Oxygen present at the place of observation, rather than the quantity discoverable in the particular part of the country in which the station is situated. This fact accounts, to some extent, for the apparent contradictions as to the relative proportion of Ozone found in the columns assigned to the different winds.

Although the amount of test-coloration during the prevalence of the various winds differs very much at the places of observation, there would seem to be an agreement in the general direction of some of the curves. (*Vide* Table 15.) A very marked depression when the wind is E. or S.E., and an elevation when it blows from a Westerly point, cannot fail to be observed. The great

Emden. depth of test-reaction at Emden when the N.W., N., and W. winds blow, is doubtless due to the exposure of the town to the sea-winds.

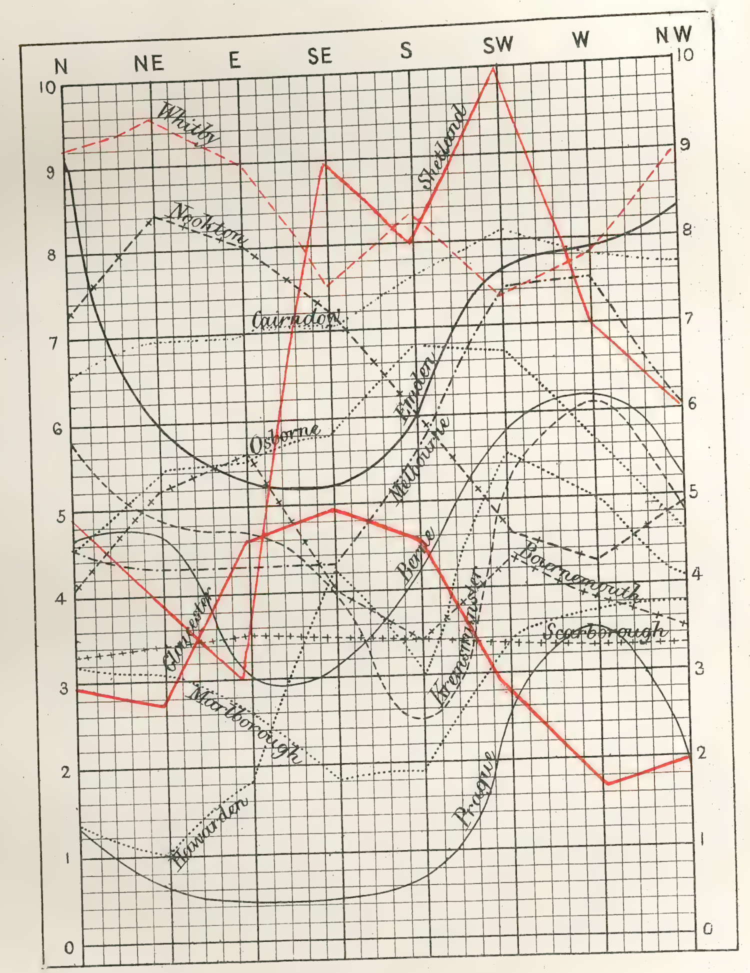
According to the observations of Bérigny[1] (conducted

Versailles. at Versailles for nine years), the S., S.W., W., and N.W. winds colour the tests more readily than those proceeding from the opposite directions. Currents of air from the Atlantic, the Bay of Biscay, and the Mediterranean, as well as the Pyrenees, are probably concerned in the production of this distinction. Bérigny thinks that the force and direction of the wind have not much effect on the

[1] *Comptes Rendus*, 1865, N. 18, p. 903.

TABLE 15.

Ozonoscopic Windrose.



coloration of the tests; whereas Prestel believes that its velocity has a great effect on it, and that its direction is all-important.

Schiefferdecker even affirms that the direction of the wind is without any influence on the manifestation of Ozone.

Scarbro'. The Scarborough curve shows the amount of coloration when the test was exposed for twenty-four hours, a mode of observation which has been adopted by some, but which, as will be hereafter shown, is attended by the most fallacious results.

Lighthouse near Whitby. In the observations at the Lighthouse near Whitby, the tests were exposed only six hours. There is no reason for thinking that the amount of purifying principles in the air of these towns varies to any extent. The duration of the exposure of the tests is probably the sole cause of the great difference in the curves.

Amiens. At Amiens, M. Decharmes states, the N.N.E. and especially the N.W. winds are the bearers of most Ozone.

Weybridge Heath. Mr. Harrison of Weybridge Heath sees a relationship between the course of the sun and the development of Ozone. He writes—"Starting from its minimum (2·24) value in the East, the amount of Ozone regularly increases through the Southern points until it attains its maximum (4·17) in the S.W., and then as regularly, but more rapidly, declines through the W. and N. to its original minimum in the East."

Edinburgh. The Edinburgh observers, in their experiments at the Botanic Gardens, noticed a considerable amount of Ozone with a N.E. and N.W. wind, but a minimum or entire absence of it with the wind in any quarter from S.E. to N.E., and especially from S.E. and E. The city and the meadows irrigated with sewage lie in these directions, the latter being about two miles from the place of observation.

Brighton. At Brighton, Mr. Sawyer tells us, the S. and S.W. which pass over the town before they reach the place of observation, contain no Ozone; whilst there is always an

abundance with N.W. and N.E. winds which come fresh from the Downs.

Eastbourne

At Eastbourne the ozonic reaction is greatest when S. and W. winds blow. It is least, and often *nil*, when they come from the N. and E.

Bath.

At the station close to Bath, most Ozone is noticed during the prevalence of winds from points between N. and E. S. and W. winds, which are most numerous, bring smoke from the city and a minimum of Ozone.

Guernsey.

At Guernsey, the greatest amount of test-coloration accompanies W.S.W. and N.W. winds; and the least is simultaneous with a S.S.E. current.

Culloden.

At Culloden, the greatest manifestation of Ozone occurs when the wind is S. or W.; and the least coloration when it blows from points between N. and E.

I. of Islay.

In the Island of Islay, Hebrides, the ozonic coloration is found to be most intense with the moist Westerly winds.

Cockermouth.

At Cockermouth, Ozone is most abundant with S. or S.W. winds, and least so with those from N. or E., being often absent for days together, when the wind is from either of the last-named points, or is approaching them.

Shetland Isles.

Mr. Matthewson of Lerwick, Shetland, states that the Ozone papers are influenced more by the damp, rainy or misty air, than by the direction of the wind.

Streatley Vicarage, Berks.

The Rev. J. Slatter, of Streatley Vicarage, Berkshire, finds that his Ozone tests yield maximum tints when the wind blows from the English Channel (distant about 70 miles), and minimum tints with a polar current.

Worthing.

At Worthing, Mr. Harris has observed the greatest amount of coloration with S.W. and the least with polar winds.

The "hot winds" of Australia.

The "hot winds," with which we are happily not practically acquainted in this country, are said to be destitute of Ozone. Mr. Brough Smyth, F.G.S., Director of Meteorological Observations in Victoria, finds[1] from an examination of the records of the Melbourne Observatory that during a hot wind the readings have been as low as 1 or 2 (Schönb. scale), and that a sudden change of the wind to W. or South-Westerly points has been attended by an increase of coloration to 8, 9 or 10. He has noticed that the greatest amount of Ozone is registered during *changes of wind* from some Northerly to a Westerly point—a fact which would indicate that high readings of ozonoscopes are connected with great electrical disturbances.

[1] *Australian Med. Journal*, January 1859.

CLOUDS.

(*d*) Clouds.

(α) Amount of clouds.
(β) Kind of clouds.
(γ) Height of clouds.

(α) Amount

(α) Bérigny and Decharmes both affirm that the more the sky is covered with clouds, the greater is the quantity of Ozone. Reslhuber made the following comparison between the amount of this body during a cloudless and a cloudy sky at Kremsmünster.

The quantity when the sky is cloudless:—

	Day.	No. of Observ.	Night.	No. of Observ.	Mean.
From October to March .	5·67	(12)	5·62	(24)	5·65
„ April to September .	2·36	(29)	3·18	(46)	2·77
Mean of entire year 1855 .	3·32	(41)	3·87	(70)	3·60

The quantity when the sky is overcast without any aqueous precipitations:—

	Day.	No. of Observ.	Night.	No. of Observ.	Mean.
From October to March .	5·70	(77)	5·84	(65)	5·77
„ April to September .	3·91	(32)	4·23	(44)	4·07
Mean of entire year 1855 .	5·17	(109)	5·20	(109)	5·19

Scoutetten thinks that a cloudless state of the sky is only an indirect cause of the diminution or absence of Ozone, and that the direct cause is the comparative dryness of the air which usually accompanies it.

(β) Kind.

(β) Reslhuber found that the appearance of cirro-strati coincided with the maximum amount of Ozone, and that of cirro-cumuli with a minimum quantity.

The mean quantity accompanying the different kinds of cloud:—

	Day.	No. of Observ.	Night.	No. of Observ.	Mean.
With Cirro-cumulus .	1·00	(2)	2·40	(4)	1·70
„ Cirrus . .	3·13	(18)	3·35	(14)	3·24
„ Cumulus . .	3·62	(111)	4·23	(63)	3·93
„ Cumulo-stratus .	5·28	(106)	6·37	(79)	5·83
„ Cirro-stratus .	6·56	(76)	6·27	(117)	6·42
„ Stratus . .	5·23	(36)	5·39	(43)	5·31

(γ) Height. (γ) Baxendell has traced a connection between the height of the clouds and the amount of Ozone detected on the surface of the earth.

Glaisher proved long ago that the atmosphere usually consists of several strata of air, which are separated by distinct boundaries from one another and do not freely mix. As the Ozone in the lowest stratum of air is only under most circumstances available for examination, its quantity will be proportioned, *cœteris paribus*, to the thickness of this stratum. Professor Jevons has pointed out that the upper limit of the lowest stratum is usually defined by the height of the first layer of clouds, and that the quantity of Ozone which reaches the surface depends on—

Professor Jevons.

1. The thickness of the lowest stratum of air;
2. The proportion of Ozone existing therein; and,
3. The degree in which this most inferior current of air is rendered uniform by constant mixture.

Mr. Crosthwaite. The observations of Mr. Crosthwaite show that the height of the lowest current of air is greater in May than in any other month. In such a case a larger mass of air is able to come successively in contact with the surface of the earth, and furnish indications of the amount of Ozone it may contain. Mr. Buchan, the Secretary of the Scottish Meteorological Society, informs us that May is the month of maximum, and November is that of minimum Ozone development at the Scotch stations. February and May would seem to be at the majority of stations the two months of maximum ozonic reaction.

In November, which generally, on the other hand, affords minimum indications, the earth is covered for the most part with a stagnant layer of air that is polluted with its exhalations. The air does not undergo the salutary process of an active admixture by the winds. The sun, whose rays also occasion a perpetual circulation or convection in the lowest mass of air, exerts but little heating effect during this foggy month.

The comparative electrical and ozonometric observations of Reslhuber at Kremsmünster, during periods characterized by the meteorological phenomena which have engaged our attention, being unique, are deserving of passing notice. The amount of electric tension is expressed in the degrees of the circle of Lamont's Electrometer. Reslhuber's comparative electrical and ozonometric observations.

	Electricity observed 2 or 3 times during the exposure of Ozonoscopes.	Ozonoscopes (Schönbein's) exposed 2 hours.
With a clear sky	1·3°	0·5°
„ Cirro-cumulus and Cirrus	1·3	0·4
„ Cumulus	1·4	1·8
„ Cumulo-stratus	1·7	3·6
„ Cirro-stratus, clouds coming almost from the ground with rainfall	1·5	4·6
„ Very warm weather	1·0	1·1
„ Very cold weather	3·0	5·0
„ Dry air	1·6	0·6
„ Damp air	1·6	4·0
„ East wind	1·7	1·0
„ S.E. „	·9	·4
„ S.W. „	1·4	4·6
„ W. „	1·7	4·0
„ N.W. „	1·2	3·6
„ Fog (rising from the ground)	1·5	3·7
„ Fog (high in the air)	2·4	2·5
„ Rain (very feeble, heavens presenting a thunderstorm-like appearance without any electrical discharge)	10·0	3·5
„ Feeble rain	1·8	4·0
„ Very fine rain	·8	4·0

	Electricity observed 2 or 3 times during the exposure of Ozonoscopes.	Ozonoscopes (Schönbein's) exposed 2 hours.
With Heavy rain	1·8	6·0
„ Pouring rain	1·3	5·0
„ Thick rain	·4	6·0
„ Fog and rain	·0	3·0
„ Snow	3·0	4·7
„ Thunderstorms, especially *distant* ones, accompanied by rain	max.	4·5
„ „ Unaccompanied by rain	max.	·5
„ „ Accompanied by feeble rain	6·9	2·5
„ Thunderstorms in *close* proximity, accompanied by torrents of pouring rain	max.	6·5
„ „ Accompanied by hail and rain	max.	6·0
„ „ Accompanied by rain	max.	3·5
„ Thunderstorm passing across the zenith, which was accompanied by strong hail and "waterspout-like" rain	max.	10·0

Reslhuber arrives at the following conclusions, as the result of these synchronous Ozone and electrical observations :—

His conclusions.

1. That with clear sky, dry air, great heat and high clouds, a small degree of Electricity and of Ozone is found in the air.

2. With low clouds and tendency to rainfall, there is a low degree of Electricity and a higher one of Ozone.

3. With a cold and clear sky, there is a high degree of Electricity and of Ozone.

4. With damp air, a low degree of Electricity and a higher one of Ozone.

5. With East winds, a low degree of Electricity and of Ozone.

6. With West winds, a lower degree of Electricity and a higher one of Ozone.

7. With fogs rising from the ground, a lower degree of Electricity and a higher one of Ozone.

8. With high fogs, on the contrary, a higher degree of Electricity and a moderate amount of Ozone.

9. With feeble rain and clouds resembling thunder-clouds, a higher degree of Electricity and a moderate amount of Ozone.

10. With fine, close and strong rain, a lower degree of Electricity and a higher one of Ozone.

11. With snow, a higher degree of Electricity and of Ozone.

12. With thunderstorms, all the observations show that the amount of Ozone reaction depends altogether on the amount of aqueous precipitation. When a storm is at a distance, the Electricity and the Ozone reaction are very weak. As soon as the clouds reach the zenith of the place of observation, a greater electric tension and a stronger test-coloration are noticed when aqueous precipitations take place. Under these circumstances, the larger the fall of water is, the deeper are the test tints.

Explanation of apparent contradictions.

He thus explains the apparent contradictions :—As regards fogs and clouds, the important point which arises is, whether they *are* or *are not* in *connection* with the earth.

1. If they *are* in good conducting communication with its surface, by means of a mountain summit, or by means of rain, or a large amount of moisture in the air, the Electricity leaves a part of the earth and passes to the surface of the cloud, giving rise to feeble electrical tension. It can thus be readily understood that there must be a low degree of tension, when clouds are passing near the ground and lying on its surface, as in No. 2; when the air is damp, as in No. 4; when the humid S.W. and W. winds blow, as in No. 6; when fogs arise from the earth, as in No. 7; and when there is fine, close and strong rain, as in No. 10.

2. When clouds are *not* in connection with the earth. Lamont considers that every body contains latent Electricity in an uncertain quantity, which, by the approach of another electrical substance, is set at liberty according to known laws. A cloud positively charged induces negative Electricity at the nearest part of the earth's surface, which combines with the permanent Electricity of the earth, a stronger tension being produced. "A cloud negatively charged induces positive Electricity and repels the permanent Electricity of the ground, so that, according to circumstances, a smaller amount of negative Electricity, or a complete annihilation of Electricity, or a positive Electricity, may be the result. These considerations will explain Nos. 8, 9, 11, and 12."

PRESSURE OF THE ATMOSPHERE.

(*e*) Atmospheric pressure.

Both Dr. E. Boeckel and Dr. Schiefferdecker state that there is no appreciable connection between the variations of the pressure of the air and those of the amount of Ozone.

Drs. Boeckel and Wolf.

Dr. T. Boeckel and Dr. Wolf think that they have traced some relationship, and that the barometric means are to a certain extent in inverse proportion to the Ozone means.

	Bar.	Ozone.
March	746·52	4·89
May	747·23	5·79
October	749·37	3·08
November	747·94	3·19
December	751·24	3·62

Dr. Moffat.

Moffat thinks that "the quantity of Ozone is *greater* with decreasing readings of the barometer, and when they are *below* the mean, than with increasing readings, and when they are *above* the mean; and that it is greater when the range of the barometer and the number of its oscillations are above the mean."

Mr. Lowe.

Mr. Lowe of Beeston gives the following results of the observations at his observatory during four years:—

With a mean maximum barometric pressure of 30·22 inches, the mean amount of Ozone is 1·0.

With a mean minimum barometric pressure of 29·18 inches, the mean amount of Ozone is 3·2.

With the Bar. at		$28\frac{1}{2}$	inches,	the mean amount of	Ozone is	5·7
"	"	$28\frac{3}{4}$	"	"	"	4·1
"	"	29	"	"	"	3·5
"	"	$29\frac{1}{4}$	"	"	"	2·8
"	"	$29\frac{1}{2}$	"	"	"	2·0
"	"	$29\frac{3}{4}$	"	"	"	1·6
"	"	30	"	"	"	1·3
"	"	$30\frac{1}{4}$	"	"	"	·5
"	"	$30\frac{1}{2}$	"	"	"	·4

"Supposing," he writes, "that the amount of Ozone in a cubic foot of air be represented by 5, at a pressure of $29\frac{1}{2}$ inches, ought it not to be more than 5 when this pressure is increased, and less than 5 when diminished? Yet the contrary is shown to result in practice." Although several observers concur in perceiving a certain connection between the weight of the air and the amount of Ozone, it is questionable whether there is more than an indirect one. It must be remembered that a low barometric pressure is almost invariably attended either by high wind or an aqueous precipitation.

The influence of the humidity and temperature of the air on the production of Ozone is elsewhere alluded to. (*Vide* pp. 271 and 276.)

(*f*) Phases of the moon. PHASES OF THE MOON.

The amount of Ozone has been thought to be greater when we have a new and full moon than during the first and last quarters. If this is the case, it may be accounted for by the facts that a larger amount of rain falls and a greater number of days are rainy at the periods of new and full moon than at those of the first and last quarters.

(*g*) Eclipses. ECLIPSES.

During the solar eclipse of March 15, 1858, ozonoscopes underwent a deep coloration. At Oundle the ozonic reaction was noted as excessive, and at Guernsey, Dr. Hos-

kins, F.R.S., says, the abundant development of Ozone was the most interesting and remarkable phenomenon which he noticed. The night preceding the eclipse yielded a maximum discoloration of tests, namely 10. From 9 A.M. to 3 P.M. on the 15th it was equal to 8; from 3 to 9 P.M. the reading was 7, making a total of 15 in the twelve hours—a much larger amount than he had hitherto observed, even after a lapse of a period twice as long.

ASTEROIDS and great fluctuations of temperature.

(*h*) Asteroids.

Some connection has been suggested by M. Ch. Sainte-Claire Deville between the occurrence of the extremes of ozonic reaction in the spring and autumn, and that of the passage of large numbers of Asteroids, which, in conjunction with excessive fluctuations of temperature, are phenomena peculiar to those seasons.

EARTHQUAKES.

(*i*) Earthquakes.

Dr. Grellois, of Constantinople, states that the emanations which are disengaged during Earthquakes appear to destroy the Ozone present in the air. Dr. E. Boeckel, on the other hand, has never noticed any increase or diminution in the amount of Ozone during "tremblements de terre."

Speaking generally, it may be said that Ozone is contained in the air in larger quantity during the winter and spring months than during the summer and autumnal ones. Why? Winter and spring are especially characterized by rain, snow, hail, a maximum of Electricity, low temperatures (hence a minimum of decomposing and noxious principles) and high winds. The great activity of vegetable life during the latter season must not be forgotten.

Summer and autumn are, on the contrary, distinguished by high temperatures, a maximum of air-pollution owing to the decomposition of a comparatively large amount of animal and vegetable matters, by a minimum of Electricity in the lower atmospheric strata, and by the infrequency of gales.

2. WHEN SHOULD OZONE BE OBSERVED?

Constantly. Unless aspirators of an enormous and cumbrous size be used, the unceasing observation of Ozone cannot be conveniently managed, except by the employment of the tube aspirator, in the working of which a constant supply of water is requisite. One of the causes of the manifestly erroneous conclusion of Mr. Smyth, who believes that the amount of Ozone in the atmosphere does not vary, is probably to be found in the extreme brevity of the periods during which his ozonoscopes were exposed. He suggests that observers should make daily observations (five minutes in duration), by means of an Andrews' aspirator capable of holding one hectolitre (22 gallons), and of passing about 831·822 cubic inches of air over a test per minute, which is equivalent to about 49,909 cubic inches, or rather more than 16 miles per hour. Air cannot be passed at this velocity over a test containing free Iodine without a great loss of this metalloid by volatilization. If the Iodized Litmus test be employed, which measures the Ozone by the quantity of Potash produced, instead of by the amount of Iodine that is liberated, there is great waste of force. Sufficient time is not given, when air of such velocity is used, for the Ozone to act on the ozonoscope during its rapid passage over it. It is, moreover, quite absurd to suppose that a single observation, conducted daily for five minutes only, can indicate the comparative amount of Ozone present in the air during the space of each twenty-four hours. Not that there is any objection to a five minutes' trial, twice or even thrice a day, as supplementary to constant and never-ceasing observation. We want to know the maximum amount of Iodide of Potassium decomposed every twelve hours by the atmospheric Ozone. In addition to an experiment at the commencement and expiration of that time, some estimate of its quantity is needful *during* that period if we would obtain this information.

WHERE

IS OZONE OBSERVED IN THE ATMOSPHERE?

WHERE
IS OZONE OBSERVED IN THE ATMOSPHERE?

THIS query will be most conveniently answered by considering it under the two following divisions:—

1. Where has Ozone been observed?
2. Where should Ozone be observed?

1. WHERE HAS OZONE BEEN OBSERVED?

Ozone is found in greater abundance in pure country air than in impure town air, on mountains than in valleys, at the seaside than inland, in well drained and ventilated towns than in those where these important sanitary matters are neglected.

Air-purifier.

It is nature's great deodorizing and purifying principle, that oxidizes the emanations from decomposing animal and vegetable substances with which the air is constantly being contaminated, thus rendering them innocuous. The atmosphere would be so polluted by its admixture with the noxious matters evolved during the putrefactive changes which are unceasingly taking place on the globe, as to be unfitted for sustaining animal life, were it not for the all-pervading influence of the "great disinfectant" Ozone. In thus sustaining the salubrity of the atmosphere by destroying its impurities, it, in its turn, suffers destruction. It this were not so, there would necessarily be an accumulation of Ozone prejudicial to animal and vegetable life; for it is always being produced not only on the surface of this planet, but in the wondrous envelope which encompasses it.

The oft-mentioned Schönbein discovered that air con-

Powerful purifying properties.

taining only $\frac{1}{3240000}$ of Ozone has the power of disinfecting its own volume of air loaded with the effluvia emitted in one minute from four ounces of flesh in a highly putrid state. It would thus appear that a little Ozone goes a long way.

(*a*) Absence or diminution in cities and towns.

The diminution in the amount and the occasional absence of Ozone in the air of cities and towns have been universally noticed, and been ascribed to its consumption in the oxidation of the noxious exhalations and products of combustion, inseparable from all aggregations of human beings. Dr. Richardson observed, some time ago, that Oxygen loses its power of oxidation when it has been repeatedly passed over dead and decomposing animal matter.

Exeter.

Dr. Shapter[1] states that in the city of Exeter the amount of Ozone is at its minimum; that distance from the city increases it; and that observations on the high ground in the neighbourhood, *e.g.* Pennsylvania Hill, indicate that an increase and even a full development are almost constant.

Comparative observations at and near Bridgewater.

Mr. Haviland,[2] in order to show how this agent often abounds in the country when its presence cannot be detected in an adjoining town, conducted simultaneous observations during the first week of March 1854 at the following places :—

Stations.	Daily average.
Bridgewater	0
Halesleigh, $\frac{3}{4}$ mile from Bridgewater . .	4·2
Cannington Park, $3\frac{1}{4}$ miles from Bridgewater .	6·1

Brighton.

Faraday has noticed the same fact at Brighton.

Manchester

Dr. Angus Smith found that the air of Manchester contained no Ozone, nor was there any effect on the ozonoscopes in the country around when the air had, before reaching them, traversed the city. He agrees with Dr. Moffat in thinking that Ozone is destroyed by the products of combustion.

The subjoined arrangement exhibits the results of

[1] *Climate of Devon.* [2] *Climate, Weather, and Disease.*

Comparative observations in a city, a town, and in the country.

simultaneous observations, by means of Houzeau's *true* Ozone tests, in a city, a town, and in the country :—

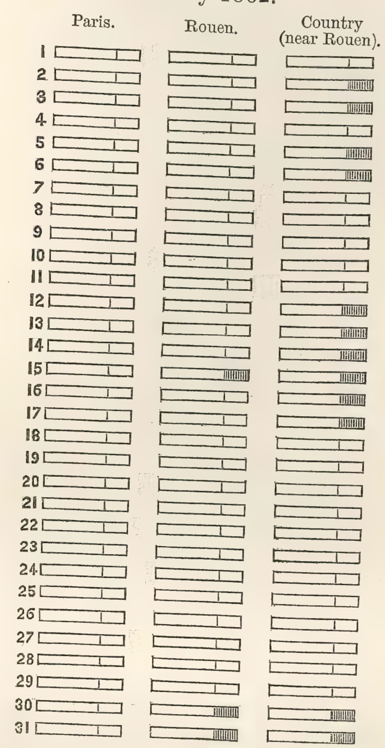
TABLE 16.

The INFLUENCE of LOCALITIES on the MANIFESTATION of OZONE.

Normal state of the half-iodized red Litmus Paper.

Its state after the action of Ozone.

January 1862.



Drs. Tripe[1] of London, J. Boehm of Prague, Rogers of Boston, and many others, have observed the deozonisation of air passing over densely populated towns. Ozone is found to be steadily deficient in large commercial cities, such as Birmingham, Greenock, Glasgow, etc.

[1] *Report of Council of Meteorological Society*, 1858; pp. 7 and 36.

In Dr. C. Evans' *Weekly Return of the Rise and Decline of Disease in London,* July 1857, he writes—

"The N.E. wind reaching Hackney from the country is found to be highly charged with Ozone, but on arriving at Fulham, after having crossed London, it appears to have lost almost all traces of this substance. Precisely the converse of this occurred on Saturday, when the wind blew from the S.W."

Silloth and Braemar. There is said to be more Ozone at Silloth, a seaport town in Cumberland, than at any other British station (annual mean 9·4). It is also declared to be in large amount at Braemar, near Balmoral (annual mean 8·9).

Prague and Weybridge Heath. Prague and Weybridge Heath, Surrey, exhibit yearly means smaller than those of any of the other stations contained in the following table.

Lyons. Lyons is notorious for the rarity of any indications of the presence of Ozone. Indeed it has been generally named "the town without Ozone." The officials of the Imperial Observatory, MM. Fournet, Lambert, Rassinier, and Bineau, have all testified to its great scarcity in Lyons. Whilst Ozone is very abundant at Sauvage and on the heights of Tararæ, traces are barely perceptible once or twice a month in this city.

Amiens. At Amiens, the mean of more than 150 observations, made by C. Decharmes,[1] yielded No. 4 (S.) The maximum (10) occurred three times, and the minimum (0) very often in parts of the city but slightly elevated.

Geneva and Chamouni. At Geneva and the Chamouni, Dr. Saunderson observed the quantity of Ozone to be very large.

Washington. Dr. Wetherill ascertained that the air of the public grounds of Washington yielded at night an abundance of Ozone, whilst that of the streets of the city, examined at the same time, indicated an absence of this gas.

[1] "De l'Ozone et de l'importance des observations ozonométriques relativement au degré de salubrité de l'air et de la marche des Epidémies."

TABLE 17.

The MEAN AMOUNT of OZONE at different Stations during the various Months.

A. Andrews. H. Houzeau. J. Jame de Sedan. K. Kreil. L. Lowe. M. Moffat. N. Negretti and Zambra. O. Iodized Starch test, of kind unmentioned. S. Schonbein.

Place of Observation.	Height above Mean Sea Level.	Test employed.	Years of Observation (inclusive).	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual Mean.	Remarks.	Authority.
Aberdeen	Ft. 105	S.	1864-1870	4·0	4·37	4·27	3·83	3·32	3·10	2·95	3·18	3·27	3·55	4·02	4·03	3·6	In W.N.W. suburbs, 1¾ mile from sea	A. Beverley.
Aldershot, Hants	325	..	1870	3·0	3·0	3·0	2·2	2·4	2·7	2·7	2·8	3·0	3·1	2·6	2·9	2·8	....	J. Arnold.
Ballater, Aberdeen	660	S.	1 year	450·5	408·	424·	387·	463·5	352·5	324·	381·5	342·	451·	433·5	473·5	407·6	Number of degrees of coloration	J. Paterson.
Bath	112	M.	1869-1871	5·1	5·2	5·2	5·1	6·5	5·2	5·7	4·9	5·6	6·0	3·6	5·0	5·2	Close to the city	C. Barter.
Bath Lit. and Scient. Instit.	71	S.	1867-1871	3·8	4·2	4·3	3·5	5·4	3·8	4·1	4·1	4·8	3·5	2·2	3·6	3·9	In the city	Secretary.
Berne	..	S.	1853-1855	8·2	9·7	8·1	6·1	7·8	8·3	5·4	5·2	4·8	5·3	7·6	7·9	7·0	....	R. Wolf.
Bombay Presidency	..	..	1863-1867	2·7	2·7	2·6	3·1	3·8	5·0	5·3	4·5	3·6	3·3	2·9	2·8	3·5	....	H. Cook.
Bournemouth	118	S.	1868-1871	3·8	4·5	5·2	4·8	5·1	3·6	3·3	3·9	3·9	3·7	3·2	4·2	4·1	....	J. A. Compton.
Braemar	1110	S.	1868, 1870, and 1871	8·9	8·9	9·0	8·9	8·9	9·0	8·8	9·0	9·0	9·0	9·2	8·9	8·9	....	Dr. Marshall.
Cairndow	25	L.	1866-1867	207·	232·	227·5	250·5	223·	225·	229·	247·	234·	233·	224·	239·	231·	Number of degrees in place of mean	A. Buchan.
Carnwath, Lanark	695	S.	1870 & 1871	5·7	6·9	5·8	6·4	5·5	5·4	6·4	5·7	5·5	6·3	4·4	4·6	5·7	....	W. Currie.
Cockermouth	158	M.	1862-1870	2·1	2·1	1·2	2·0	1·9	2·1	1·5	1·4	1·9	1.1	1·1	1·8	1·7	....	H. Dodgson.
Culloden	107	S.	5 years	8·11	8·41	8·45	8·47	8·27	8·19	7·87	7·49	7·81	8·21	7·90	8·22	8·1	4 miles E. of Inverness	A. Forbes.
Dover	52	M.	1870	1·32	1·30	2·12	1·60	3·48	2·70	2·51	·50	1·70	·09	0·0	·07	1·45	Great mortality amongst children towards end of year	Dr. Parsons.
Dublin	158.8	A.	1870	·4	·5	·5	·6	·5	·5	·3	·4	·4	·6	·5	·4	·5	....	Ord. Surv. Off.
Dumfries	159	S.	1870	5·27	6·28	6·19	6·78	6·83	7·25	6·64	6·60	5·83	6·00	4·00	5·08	6·06	80 yards N.E. of Crichton Institution	A. Bruce.
Dunse, Berwick	500	S.	1868-1870	6·2	7·3	7·0	6·8	7·5	7·2	6·7	7·3	7·1	6·6	5·8	6·6	6·8	At base of Lammermoor Hills	P. Loney.
Eastbourne	45	S.	1867-1870	4·3	5·7	3·8	4·4	6·0	4·3	5·6	4·9	5·4	3·8	3·5	4·8	4·7	....	W. Hall.
East Linton, Haddington	90	S.	1864-1868	5·5	6·0	6·3	6·3	7·6	6·4	6·3	6·5	6.3	5·1	4·1	5·8	6·0	3¾ miles from the sea	J. Storie.

TABLE 17.—*Continued.*

Place of Observation.	Height above Mean Sea Level.	Test employed.	Years of Observation (inclusive).	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual Mean.	Remarks.	Authority.
East Yell, Shetland	Ft. 176	S.	1868	6·10	7·14	6·00	6·32	5·60	6·0	5·07	5·98	5·42	4·92	3·82	5·66	5·58		
Eccles, near Manchester	..	..	1867 & 1868	2·93	4·03	4·59	4·63	3·08	2·79	2·27	3·42	2·13	2·17	1·86	3·35	3·10	Exposed in louvre box	A. Matthewson.
Emden	..	S.	1857-1863	5·90	6·42	7·79	7·42	6·56	6·17	5·59	5·90	6·19	5·76	4·77	5·93	6·2	....	T. Mackereth.
Exeter	..	..	6 years	3·6	3·3	3·7	3·4	4·0	5·5	4·6	4·3	3·4	3·5	3·0	3·4	3·8	....	M. Prestel.
																	3 years in Barnfield, 1½ at Elmbrook, and 1½ at St. Leonards	T. Shapter.
Galashiels, Selkirk	368	S.	1868, 1870, and 1871	2·9	6·0	5·2	4·9	4·9	4·3	3·4	4·1	3·1	3·4	3·3	3·7	4·1	....	R. Somerville.
Gloucester	100	S. & M.	part of 1867, 1868, 1869, part of 1870, ,, 1871	1·83	1·85	1·71	2·84	4·3	3·41	3·44	2·9	3·85	·79	·92	1·63	2·45	....	E. Toller.
Guernsey	204	M. 7 yr; S. 7 yr	1857-1870	4·14	4·33	4·42	4·50	4·28	4·56	4·00	4·04	4·31	4·10	4·01	4·26	4·25	Excess of colour during Solar Eclipse, Mar. 1858	E. Hoskins.
Halifax	630	S.	1869-1871	1·5	1.9	2·3	2·2	2·5	3·8	1·7	2·1	1·2	2·2	2·2	1·2	2·3	....	L. J. Crossley.
Hawarden	270	M.	20 years	..	2·6	..	..	2·5	..	..	1·0	..	..	2·6	..	2·2	Quarterly mean is inserted	T. Moffat.
Helstone	110	M. & S.	1860-1870	4·4	4·2	4·4	3·7	4·0	3·2	2·9	3·3	3·6	4·2	4·0	4·5	3·9	....	A. Moyle.
Hobart Town, Tasmania	..	S.	1857-1870	6·93	7·17	7·11	7·06	6·85	6·61	7·10	7·56	7·92	7·91	7·50	7·11	7·24	....	F. Abbott.
Hull, The Park	High water mark.	S.	1870	2·3	2·8	5·2	2·7	4·4	4·0	3·2	5·2	2·2	3·4	2·4	1·4	3·3	....	E. Peak.
Isle of Islay, Hebrides	70	M.	1870	8·20	8·33	8·09	7·82	8·30	7·70	7·77	7·40	7·63	7·38	8·08	7·88	7·88	....	R. Ballingall.
Königsberg	70	S.	1852-1853	8·8	10·9	11·2	10·8	8·1	5·5	4·8	5·2	7·1	8·2	7·5	9·2	8·1	....	Schiefferdecker.
Kremsmünster	..	S.	1854-1855	7·28	7·78	6·45	4·82	4·29	4·58	3·45	3·42	4·01	4·87	6·01	6·31	5·27	....	M. Reslhuber.
Lampeter, Cardigan	420	..	1870	6·5	4·7	4·5	4·5	4·5	4·5	3·0	3·6	4·0	5·3	4·4	3·9	4·4	....	J. Matthews.
Lisbon	328?	..	1866-1867	7·85	6·11	7·84	5·40	6·11	4·83	3·79	3·98	4·04	4·45	4·96	6·04	5·45	....	E. Brandt.
Malvern	500	S.	1870-1871	3·7	5·7	4·9	4·7	5·1	4·7	4·2	5·4	5·4	4·8	4·2	4·4	4·8	....	W. Burrow.
Marlborough	456	S.	1864-1871	3·9	4·4	4·0	3·3	3·2	2·8	3·0	3·1	2·7	2·3	2·4	2·8	3·1	....	T. A. Preston.
Melbourne Observatory	..	S.	1857-1858	2·8	..	..	4·5	5·5	7·3	6·0	6·2	6·6	6·8	4·6	3·3	..	....	B. Smyth.
Millbrook, Jersey	50	S.	1866-1870	6·6	7·0	7·0	6·9	6·5	6·1	6·2	6·3	6·5	6·5	6·2	6·7	6·5	Exposed in louvre box	P. Langlois.
Miltown, Banbridge	200	N. L. S.	1863-1871	5·6	6·2	5·7	5·5	4·7	3·9	3·6	3·6	4·2	4·5	4·6	5·4	4·8	2 miles from Banbridge. Air very free from smoke	J. Smyth.
Montrose, Forfar	200	S.	1870	4·8	5.5	5·9	4·4	4·5	5·3	5·0	6·1	5·1	5·1	5·0	5·2	5·1	....	J. Howden.
Nancy	..	S.	1854	4·05	6·05	4·55	6·45	7·65	7·60	6·60	6·00	4·10	4·40	4·30	5·21	5·58	....	M. Simonin.
Nookton	80	S.	1861-1870	3·3	4·7	4·5	5·1	5·5	5·2	4·6	4·8	4·2	3·9	3·1	3·3	4·3	....	W. M. Millar.
Nottingham	238	S.	1868-1870	·8	1·9	3·6	1·5	2·6	2·5	1·9	2·3	1·7	·7	·7	·9	1·8	....	M. Tarbotton.
Oporto	..	..	1869 & 1870	11·0	10·0	10·0	7·5	9·0	6·0	6·5	7·5	6·5	7·5	8·0	10·0	8·5	....	J. Kopke.
Osborne, Isle of Wight	172	M.	1858-1869	5·4	5·5	6·0	6·2	6·2	6·1	5·1	5·4	5·5	5·8	5·3	5·1	5·6	....	J. Mann.
Oxford	210	S.	1870	2·5	3·5	3·0	2·4	3·1	3·0	3·0	4·9	3·7	3·6	1·9	1·2	3·0	....	R. Main.
Paris	..	O.	1866 & 1867	2·7	3·7	2·8	4·1	3·9	4·1	4·5	3·3	3·5	2·4	2·0	2·4	3·3	Scale of 20 degrees employed	M. Belgrand.
Prague	..	K. S.	1854-1857	·64	1·14	1·41	1·36	1·62	1·92	2·04	2·00	1·11	·56	·80	1·56	1·34	....	J. Boehm.
Rouen	124	H.	1861-1870	36	54	117	128	160	159	122	93	81	63	49	36	91	Number of days when tests colour	A. Houzeau.
Sidmouth	30	S.	Oct. 1865-	5·6	5·7	4·3	6·4	6·4	6·6	5·6	7·1	6·7	5·5	4·9	5·5	5·9	Tests not exposed in *dense* part of town	J. I. Mackenzie.
		M.	Ap. 1870	5·2	5·7	4·6	6·2	..	..	..	..	..	5·9	5·0	6·0	..		
Silloth, Cumberland	28	M.	1868 & 1871	9·6	12·8	10·7	9·6	8·7	7·4	7·7	7·5	9·6	9.6	9·0	10.3	9·4	....	F. Redford.
Smeaton, Haddington	100	S.	1868, 1870, and 1871	4·5	5·6	5·8	4·9	5·2	4·2	4·4	4·5	4·8	4·3	4·5	4·2	4·7	....	T. Hepburn.
Somerleyton Rectory, Suffolk	50	S.	1869-1871	7·3	7·6	7·4	7·2	7·0	7·3	6·5	6·7	7·1	6·7	6·3	7·0	7·0	Near a large wood	C. Steward.
Spital, near Carlisle	113½	S.	12 years	150·0	154·2	165·5	152·8	150·0	153·3	141·5	153·0	145·5	143·0	130·0	132·5	147·6	Total number of degrees of colour.	J. Cartmell.
Stornoway, Isle of Lewis, Hebrides	70	S.	1868, 1870, and 1871	5·8	6·3	6·6	5·8	6·3	5·6	5·0	5·4	5·8	5·9	6·4	6·4	5·9	....	J. Matheson.
Strathfield Turgiss	197	..	1871	4·5	5·0	5·3	4·6	4·7	4·2	3·2	4·2	3·4	4·0	3·9	2·7	4·1	....	C. Griffith.
Strasburg	..	S.	1854-1864	4·2	4·0	4·8	5·2	5·7	5·2	4·5	4·3	4·4	3·0	3·1	3·6	4.3	....	T. Boeckel.
Taunton	80	S.	1870	2·2	1·8	2·0	3·2	5·5	6·3	4·3	6·5	5·5	7·0	5·0	4·35	4·5	Observations in the town during first 3 months, and ½ a mile from it during remaining 9 months	W. Tuckwell.
Thorshavn, Faroë Isles	12	M.	1870 & 1871	6·6	5·9	6·2	5·7	6·8	6·2	7·7	7·2	7·7	7·2	7·2	7·4	6·8	....	P. Holten.
Toronto Observatory	342	..	1859	6·1	6·0	9·6	5·5	9·3	8·1	7·9	9·2	8·4	6·3	7·1	7·7	7·6	....	G. T. Kingston.
Ventnor, Isle of Wight	150	N.	1869 & 1870	6·1	6·2	5·8	5·1	5·0	4·2	3·5	4·2	5·3	5·1	5·2	4·9	5·0	Tests free from all town influence	J. B. Martin.
Versailles	..	S. & J.	1856-1864	747	688	899	834	907	816	785	792	783	727	643	731	779	Total number of degrees of colour given	Dr. Bérigny.
Vienna	..	S.	1854-1855	5·23	7·90	5·71	4·25	4·30	3·75	3·35	3·60	2·70	5·01	2·90	3·90	4·06		
Weybridge Heath, Surrey	150	S.	1861-1871	3·37	3·71	3·68	3·63	3·28	3·17	2·52	2·76	3·26	2·66	2·78	2·98	3·15	3½ m. S.E. from Chertsey	W. Harrison.
Whitby, Lighthouse near	200	S.	1870-1871	8·1	8·6	8·5	8·8	8·0	8·1	6·8	8·6	7·9	8·4	6·0	8·6	8·0	....	F. Stow.
Wilton House, near Salisbury	150	..	1870	4·7	4·2	3·4	3·2	4·3	3·7	3·1	3·8	4·2	5·2	5·1	4·6	4·1	....	T. Challis.
Wisbech, Cambridge	14	..	1870	3·0	3·6	4·7	3·8	5·1	6·7	4·8	6·2	3·1	4·2	1·7	1·6	4·0	....	S. H. Miller.
Worthing	21	S.	1861-1871	3·8	4·1	3·8	4·7	5·6	4·1	4·8	4·4	5·2	3·2	2·1	3·2	4·1	Close to seashore	W. Harris.

(*b*) Seaside stations.

The means at the seaside stations exhibit a striking uniformity, and an enormous amount of Ozone. The registers of small islands, such as Islay, Guernsey, Jersey, Faroë, are distinguished by possessing the same peculiarities. The observations made,[1] even during the hot months of July and August 1871, by Huizinga, with Schönbein's tests on the island of Texel, show an intense reaction. It is not surprising that the atmosphere, in the vicinity of one of the greatest manufactories of Ozone, should be generally saturated with this body. It is probable that on those days, when maxima are not registered at lighthouse stations or on small islands, the coloration of the test paper is simply interfered with by the temperature or excess of humidity, etc., so powerful is the local determining influence to which ozonoscopes in such positions are subjected. The Rev. F. Stow, who conducted the observations at the lighthouse near Whitby, found the sea air so abundantly loaded with the body or bodies which colour the tests, as to render it extremely difficult to estimate their highest tints. The amount of Ozone present in the air of Scarborough, which is open to the sea in the N., N.E., E., and S.E. directions, varies little, by reason of the constant impregnation of its atmosphere with sea air. The proximity of other manufactories—

(*c*) Stations near forests, etc.

viz. forests, woods, and plantations of firs—interferes also with the normal coloration of the tests. The records of M. Bérigny, of Versailles, show the influence of the vicinity of forests and other vegetation on the amount of Ozone. The maximum is in May when vegetation is active, and the minimum in November when the decomposition of the dead leaves and plants, and the humidity of the air, are the greatest. The returns of M. Houzeau cannot well be compared with those of other observers, as the tests which he employs are constructed on a different principle, and only register maximum amounts of Ozone. His observations show that the greatest

[1] *Journal für praktische Chemie*, 102, 201.

number of maxima occur at Rouen in May and June, and the greatest number of minima in January and December. M. Beaumont thinks that these results are also determined by the amount of vegetation about Rouen, which in this respect resembles, to a certain extent, Versailles.

It will be remarked that the reports from the various stations contained in the foregoing table differ very much from one another. As we are unable to find two men or women precisely alike, so is it equally impossible to discover two towns or stations possessing a climate identically the same. As each health resort is distinguished from all others by certain meteorological conditions of its own, so, Angus Smith assures us, every mountain, wood, field and even house, has its own peculiar climate. It may be urged that the table is worthless as affording any basis for comparison, because different tests have been employed, and the observations have not been conducted during the same space of time. My reply to this objection is, that if the same kind of test be used during the same period, widely dissimilar results are also encountered.

The following table comprises a mean of the day and night observations made, under the superintendence of the Central Club of Vienna, at fourteen stations with Schönbein's ozonoscope.

TABLE 18.

1855.	Vienna.	Kahlenberg.	Cracow.	Lemberg.	Czaslau.	Szegedin.	Schemnitz.	Klagenfurt.	Salzburg.	St. Maria.	Berne.	Prague.	Kirchdorf.	Kremsmünster.
January	5·3	8·5	5·7	5·8	7·6	6·7	6·9	9·2	7·5	7·2	5·6	1·4	6·8	6·4
February	5·3	9·2	6·0	5·0	8·1	6·9	6·9	8·6	8·6	7·6	6·2	0·1	8·2	7·8
March	5·1	8·7	6·9	6·1	7·4	6·0	7·8	8·5	7·1	7·3	6·1	1·0	6·2	6·2
April	4·4	8·4	5·3	6·7	6·0	4·3	6·1	...	7·3	7·8	3·9	1·6	5·7	6·1
May	4·6	8·8	4·9	6·2	5·1	3·8	5·3	7·2	6·4	8·3	3·9	1·9	5·1	5·1
June	3·0	7·8	4·9	4·7	4·1	2·2	5·2	6·2	6·0	8·1	5·3	2·6	3·6	3·2
July	3·1	6·0	3·4	5·6	5·6	2·7	5·4	5·5	6·2	6·5	4·3	3·0	3·2	2·8
August	3·6	7·2	4·1	5·3	4·7	2·7	5·6	6·1	5·1	6·4	3·9	2·0	3·3	3·0
September	2·9	7·9	4·7	5·2	3·4	3·6	6·2	5·6	6·8	7·5	4·6	1·3	3·4	4·4
October	2·6	8·2	3·0	6·6	5·1	3·7	6·7	5·8	5·8	...	3·5	1·7	3·6	4·4
November	2·3	7·9	3·8	5·4	5·7	6·3	6·7	7·5	5·0	7·6	5·0	0·6	4·4	5·5
December	3·6	9·1	2·6	6·3	7·6	7·7	7·2	8·5	5·0	7·7	6·6	1·2	6·2	6·3
Year	3·9	8·1	4·6	5·7	6·2	4·7	6·3	7·1	6·4	7·4	4·9	1·5	4·9	5·0

Variations in the amount of Ozone at Different Heights.

It has been said that the quantity of atmospheric Ozone, like that of atmospheric Electricity, increases in proportion to the height.

Ozonic reaction is greater at elevated than at low-lying stations, and is more considerable in the pure air of the seaside than at inland places of the same altitude.

Glaisher's experiments.

Mr. Glaisher found that an ozonoscope indicated at a height of 85 feet on the sea-coast 2°·2; whilst at the same elevation inland it exhibited 0°·6. At 170 feet the coloration inland amounted to 1·3, and at 255 feet to 3·8.

Comparative observations have been made at different heights on the cathedral of Metz by Scoutetten, and on that of Amiens by Decharmes. The former observer met with results, of which the following may be considered as examples :—

Observations on Metz Cathedral.

EXPOSURE of TESTS during March 23 and April 14 on the Cathedral at Metz.

Above ground.	March 23. Deg.	April 14. Deg.
20 metres = $65\frac{1}{2}$ feet . .	1	2
40 " = 131 " . .	2	3
60 " = 197 " . .	5	8
80 " = $262\frac{1}{2}$ " . .	5	6
100 " = 328 " .	6	10

On Amiens Cathedral.

M. Decharmes, in his experiments on the Amiens cathedral, noted a more regular and progressive increase, the numbers of the Ozone scale being 0, 3, 4, 6, and 7, according as they had been placed at the base of the tower, at the first or second gallery, at the elevated part of the tower, or on the summit of the highest tower. He noticed that the maxima followed the same progression, being 4, 6, 7, 9, and 10.

Lowe states that the higher the test is hung the darker will be the colour obtained, and that the difference is as 4 to 6 between 4 feet and 35 feet above the ground.

Observations made on the Alps also show the increase of reaction as we ascend into the atmosphere.

Observations on the Alps.

	Feet.		Humidity.
Mean daily quantity from	740 to 2000 is	15 .	58
" "	2000 to 4000 "	33 .	83
" "	4000 to 8000 "	77 .	83

Havana.

Poey found that in the city of Havana the Ozone reaction diminished with the elevation, whilst in the neighbouring country the reverse was observed.

Explanation of the diminution with elevation often observed over towns and cities.

The diminution of the amount of Ozone with the elevation in towns and cities, which has been elsewhere noted, would appear to arise from the collection and aggregation of noxious gases that are raised by the warmer temperature of the streets, and are prevented from diffusing themselves by the canopy of mist which so often hovers over centres of industry.

If tests be suspended at different elevations in country air free from animal exhalations, smoke, or any other impurity, but little difference is perceptible in their tints. The progressive increase of Ozone with the height is apparent only. A diminution of Ozone in reality occurs in the lower strata of the air, which are always being polluted by the earth and its tenants.

More on mountains and at seaside than in valleys and inland.

The larger amount of Ozone present on mountains and by the seaside, than in valleys and in the interior of continents and large islands, is, doubtless, partly due to the greater purity of the air, and partly to the greater movement to which the air is subjected at elevated and exposed localities. The frequent alternation of the land and sea breezes is an important auxiliary on our coasts, in maintaining a constant movement of the atmosphere.

Variations in the Amount of Ozone at different parts of the same Town or City.

The variations in different parts of the same town are due to the relative density of population, the number of

houses, its height, its exposure, the vicinity of open spaces and manufactories, etc. etc. The difference is very striking at three separate stations in Prague.

MEAN of DAY and NIGHT OBSERVATIONS made from December 23, 1857, to February 28, 1858.

	Hradschin.		Observatory.		St. Katharina.	
	N.	D.	N.	D.	N.	D.
Prague.	2·22	·96	1·55	·88	3·95	3·74

	N.	D.
Difference between Hradschin and the Observatory	0·67	0·08
„ St. Katharina „	2·40	2·86

It may be perhaps better appreciated by a glance at the following curves.

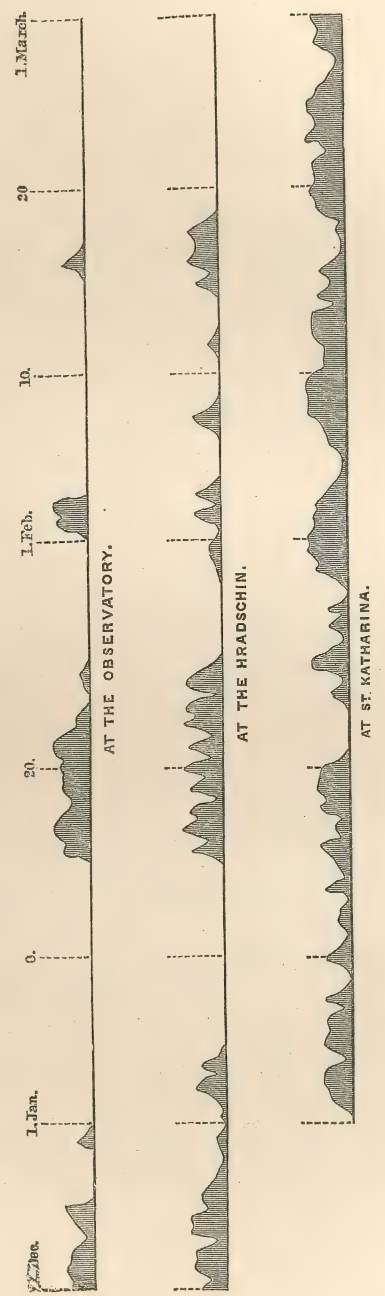


PLATE 7.

Königsberg

The observers of Königsberg, having found that the amount of Ozone detected in various parts of their city differed very much in consequence of "unascertainable local conditions," have expressed the opinion that a *single* series of observations made in a large town is not to be relied on.

Paris.

The observations organised by the municipal body of Paris[1] in the various arrondissements of that city, exhibit results, of which the majority are evidently determined by the local influences to which the tests are exposed.

Stations.	Mean of Daily Observations during the years 1866 and 1867.
Passy	(*a*) 6·39
Monceau	4·04
Montmartre	4·48
La Villette	(*b*) ·96
Charonne	4·34
Ménilmontant	(*c*) 1·16
Boulevard de Picpus	4·49
La Boule-Rouge	2·45
Fontaine-Molière	(*d*) ·38
École de Médicine	(*e*) ·80
Rue Racine	(*f*) 1·69
Panthéon	2·83
Saint-Victor	4·98
Boulevard d'Italie	3·08
Vaugirard	·89
Réservoir de Vaugirard	(*g*) 8·37
La Chapelle	(*h*) 3·08
Butte-aux-Cailles	(*h*) 4·79
	1866.
Batignolles	4·75

(*a*) Near resinous trees.
(*b*) Close to a quay on the Seine.
(*c*) Near a tallow manufactory.
(*d*) A public urinal is situated almost directly underneath the test.

[1] *Bulletin de Statisque Municipale,* February 1868.

(*e*) Close to an hospital.
(*f*) Near a reservoir.
(*g*) Suspended against the wall of a reservoir.
(*h h*) Close to artesian wells.

N.B.—The Iodized Starch tests were suspended under a porcelain plate at about the height of the first or second story from the ground. They were exposed to the East at most of the stations.

Inhabited rooms.

Ozone has been said by Professor Heaton, Mr. Burder, and others, to be always absent from the air of an inhabited room, although the window may be open. A very sensitive test suspended in a room with closed windows, situated in the country, or on the outskirts of a town, will, according to my experience, generally indicate its presence. The current of air which is always rushing towards the fireplace contains a sufficient quantity of this body to produce, after an exposure of a day or two, a very decided coloration.

Hospitals.

Ozone has been declared to be almost entirely absent from the air of hospitals, especially of those devoted to fever patients. Bérigny, Scoutetten, and E. Boeckel, have exposed slips of ozonoscopic paper in the wards of hospitals which have indicated an entire absence, or the presence of a minimum amount, of Ozone, whilst a decided coloration has been manifested in the tests suspended in the external air.

The artificial generation of Ozone in the wards of hospitals has been suggested by M. Delahousse[1] and Dr. Richardson, in order that the deleterious emanations of their diseased inmates may be oxidized. The former advocates the employment for this purpose of a platinum wire arranged in a close spiral form, which is rendered incandescent by a Bunsen's pile. A constant supply of Ozone is by these means provided.

Large amount of Ozone on the banks of Lakes, Rivers, and at the Seaside.

Accompaniments of the eva-

The evaporation of water under the influence of

[1] *Gaz. des Hop.*, No. 35.

poration of impure water exposed to air and light.

light and air has been declared to be accompanied (1) by a chemical disaggregation of the salts held by it in solution; and, (2.) by the simultaneous development of Electricity (the positive being emitted and the negative retained) which ozonises the Oxygen that is continually being disengaged from its surface. Dr. Clemens has calculated[1] that about every 13 inches of the surface of water yields ·36 of a cubic inch of Oxygen a day. When we reflect on the fact that about three-fourths of the surface of the globe are covered with water, the enormous evolution of ozonised Oxygen therefrom cannot easily be appreciated.

Dr. Clemens' calculations.

Lakes and rivers.

Remembering these statements, we are not surprised to find that tests exposed to the air over streams, near lakes, ponds, and particularly on the coasts, should colour more deeply than those simultaneously acted on by air far away from water. A test paper indicated 4 degrees when placed by Dr. Clemens at 2 feet above water, whilst another exhibited a tint of 2 degrees suspended at the same height above the soil.

Scoutetten found[2] that tests underwent a more decided coloration at about 16 inches above a deep current of water, than in the comparatively pure air present at an elevation of 49 feet from the soil.

Accident liable to occur to test.

When an ozonoscope is placed very near the surface of a rapid current, or in the vicinity of a waterfall, it will sometimes become damp; and vaporization of any Iodide of Starch that may have been formed will often occur, leaving the test colourless.

The sea winds.

The preponderance of Ozone in sea winds is unquestionable, having been noted in most parts of the world. Lieutenant Chimmo's observations in the Hebrides and on the N.W. coast of Scotland, those of Captain Jansen of Holland and Dr. Mitchell of Edinburgh, made in India, on the Atlantic, and in Algeria, all substantiate this assertion.

[1] "Malaria und Ozon," in Henle's *Zeitschrift für die Staatsarzneikunde*, 1853. [2] *Op. cit.*

Admiral Fitzroy lays down[1] the rule that the winds which accompany the greatest indications of Ozone are those which blow from the nearest and largest sea. Tests have been said to read in general $\frac{1}{3}$ higher when sea winds blow than during the prevalence of land winds. The pressure and density of the atmosphere being greater as we approach the sea level, a given volume of air of course contains a larger amount of Oxygen than the same volume taken from a level a few hundred feet higher. The excessive ozonic reaction at the seaside cannot be thus explained, but must be considered to be due to the copious production of air-purifiers in such situations. The oceans, seas, and lakes are the most gigantic and prolific of the manufactories of active Oxygen.

Dr. Burdon Sanderson suggests that the greater hygrometric condition of sea air has probably some influence in the production of a larger amount of Ozone on the coast, as the quantity of what Schönbein calls the "Strömende Electricität" must obviously vary with the conducting power of the lower strata of the atmosphere.

Purification of the air by the vaporization of water.

"The Purification of the Air by the Vaporization of Water" was the title of a communication from M. Morin to the French Academy of Sciences in 1863.[2] During his inquiries regarding ventilation he was much struck with the arrangements for imparting to the air, heated or not, which is introduced into the House of Commons, a requisite amount of moisture. A full description of these ingenious provisions for the comfort of our legislators is to be found in most works on ventilation.[3] Before a curtain which arrests the fuliginous particles of London air, as it passes into a large chamber under the floor of the house, is placed a water-pipe with a few capillary holes. The water emerging from these apertures strikes a plate of metal from which it is driven on every side in the finest possible spray. This mist mingling with the

House of Commons.

[1] *Weather Book.* [2] *Comptes Rendus*, No. 18, 1863.
[3] *Vide* F. Edwards on *Ventilation*, p. 32.

entering air is dissolved so completely, that the ground is scarcely moistened with the downfall. He thought it possible that the vaporization of the water-dust traversed by the inflowing air might be accompanied (as in the case of dew, and the rain of tempests, according to the experiments of Saussure and Pouillet) by the development of a certain quantity of Electricity, which exerts a salutary influence on the state of the air by the simultaneous evolution of active Oxygen. To ascertain if Ozone is produced in air through which water is dispersed in the form of spray, he performed the following experiment. A tube of sheet iron was arranged vertically over a water-pipe, the water from which was made to pass through wire gauze in order to pulverize it. In the interior of the other extremity of the tube, Iodized Starch tests, red Litmus papers dipped in neutral Iodide of Potassium, as well as blue Litmus slips, were suspended at a distance of one metre (39·37 inches) from the extreme point reached by the jet of spray. The result he thus describes:—

Morin's experiments.

"The current of moist air which traversed the iron tube occasioned the formation of violet or blue spots on the Iodized Starch and red Litmus tests, thus producing an action analogous to that of Ozone; and on the blue Litmus paper some red spots, indicating the presence of an Acid which was very probably a Nitrogen compound." Mons. Morin comes to the conclusion that the pulverization of water is always accompanied by the development of active Oxygen or Ozone—a change in the condition of the air which is largely produced, as we have elsewhere seen, by the passage through it of an electric current. The air in the neighbourhood of the evaporating houses of salt springs (Gradirhäusern) at Kissingen is filled with a finely-divided water spray. Its odour is popularly likened to that of the sea-shore. Gorup-Besanez has found[1] that ozonoscopes give deeper tints in the vicinity of these brine-

The air at Kissingen.

[1] *Annalen der Chemie und Pharmacie*, February and March 1872.

works than in other parts of Kissingen, and that the salt in this spray has nothing to do with the reaction, as similar results may be obtained with water-dust which contains none. We know from experience that Electricity is developed in sensible quantities in the neighbourhood of cascades, and in large amount on the sea-shore, particularly when the waves dash themselves violently against the rocks, so as to produce much spray. It has also been ascertained that sea water holds from $\frac{1}{30}$ to $\frac{1}{40}$ of its volume of air in solution. Some observations of Lewy[1] render it probable that the quantity of Oxygen in the atmosphere varies during different seasons of the year, and is not the same over the sea as in the interior of continents. Since he drew the attention of savants to this subject, it has been shown that the air in the sea contains 32 per cent of Oxygen, whilst that over land possesses only 21 per cent. This air, surcharged with Oxygen, is doubtless given off in large quantity during storms, and in a smaller amount during the ceaseless motion and agitation of the waves.

M. Lewy.

Air of sea contains a larger percentage of Oxygen than land air.

What is the cause of the exhilarating effects of the sea-breeze, and its wonderfully restorative powers in convalescence? Little is at present known as to its *modus operandi*. People talk of running down to the sea during the summer to "get a whiff of Ozone," just as if it were not possible that the little more Ozone might do them harm instead of good. The growth and vigour of plants have been proved by Mr. Carey Lea[2] of Philadelphia to be retarded and impaired in air strongly impregnated with Ozone. Simple vegetable structures, such as mould, are completely destroyed when exposed to such an atmosphere. That sea-breezes act deleteriously on vegetation we all know, but whether their blighting influence be due to the excess of Ozone, or to the Chlorides and Sulphates which

Deleterious action of sea air on vegetable structures.

[1] *Comptes Rendus*, t. xvii. p. ii. pp. 235-248.

[2] "On the Influence of Ozone and some other Chemical Agents on Germination and Vegetation," in Silliman's *American Journal of Science*, vol. xxxvii. 2d series, 1864.

are contained in the "dust of the sea," has not, I believe, been fully determined.

At the commencement of the summer of 1870, a storm from the N.E., which continued two or three days, and was accompanied by a great deal of mist and spray, visited Scarborough. The young leaves which covered the fruit-trees and hawthorn bushes were browned and blackened as if they had been immersed in boiling water. They gave very faint evidence, when made into a decoction and tested with Nitrate of Silver, of the presence of Chlorides. The air was rather low in temperature, and contained more than its normal amount of moisture. The Ozone tests yielded maximum tints. The destruction of the leaves was evidently the result either of the passage over them of a rapid current of cold air, or of an excess of Ozone. As I had never noticed a similar disaster attend long-continued *land* gales, of low temperature, possessing a feeble influence on test papers, it appeared to me probable that the injurious effects of this N.E. gale might be due to an excess of Ozone.

The vivifying and fortifying effects of sea-air on the jaded and debilitated city man, and the wonderful influences of marine medication on the sickly of all ages, are the result of many and somewhat complex agencies, and should not be considered as solely due to a residence in an atmosphere highly oxygenated, and charged with a very large amount of the most active form of Oxygen.

Cause of excitability of dwellers in cities.

It has been surmised that the want of vigour, and the excitement which mark the majority of the inhabitants of cities, is to some extent the result of the large amount of organic matter contained in the air, or of the artificial oxidation which their blood undergoes in respiration. Dr. A. Smith has found[1] that the acid vapours present in the air of Manchester redden blood more than the ozoniferous sea breezes. This abnormal reddening is not productive of an effect identical in its nature with that induced

[1] *Air and Rain.*

by the Oxygen only, which is the agent concerned in the natural aeration of this fluid. He writes, "If acids assist the oxidation of the blood in the same manner as they do the oxidation of many other bodies, then they cause the action of the lungs to go on more rapidly, and hasten the current of animal life, producing that greater restlessness of the system which is the peculiarity of great towns." Sea-air would seem to be less exciting and more invigorating than town-air. May not the activity of mind of the dwellers in cities, and the mental lethargy of the "clod" and the sailor, be explained by these considerations?

Dr. Lichtenstein and the perspiration.

Dr. Lichtenstein of Berlin states that he has found Ozone (?) in the perspiration, and in the air expired by the lungs of sick and healthy persons. Sometimes no trace of Ozone could be discovered by him, whilst in other instances the amount of this substance was very large; the quantity being quite independent of that contained in the atmosphere, or of the amount of the perspiration. Dr. Lichtenstein is hopeful that ozonoscopic observations on the sudoriparous secretion and on the breath will eventually prove of great service in the diagnosis, prognosis, and treatment of disease!

Pine forests.

Invalids are sent to the pine forests of Prussia and other countries, in order that they may breathe the highly ozonised exhalations of the Coniferæ. The beneficial effects of such a residence in pulmonary affections may perhaps be due, to some extent, to the direct influence of the Turpentine diffused through the air. All physicians are acquainted with the salutary changes produced on the mucous membranes, when in a morbid state, by this resinous exudation.

2. Where should Ozone be observed?

Everywhere. Observations as to the comparative quantity of this body present in the air should be con-

ducted in all parts of the world and at all seasons of the year. They must first be made on the purest air, under the many and various meteorological conditions of pressure, temperature, and humidity. When the normal amount of purifying principles, and the variation in their quantity under the different states and changes of the atmosphere are known, we shall then, and not till then, be in a position to carry on similar observations on the air of towns and places where epidemics prevail, in fact, on air more or less impure.

First in pure air.

At every marine and inland health-resort in the world, observations should be made with the greatest care, in accordance with the improved method.

For reasons to be hereafter given (pages 259 to 260), we should not operate on air as high as five or six feet from the ground, but should employ a lower stratum and protect the tests from any exhalations that may arise from the soil.

There is no necessity, after what has been already said, to point out as to where Ozone should not be observed. The importance of establishing stations in positions where the air cannot possibly become impregnated with the effluvia from accumulations of decomposing matters cannot be over-estimated, if we would obtain truthful results.

WHY

IS OZONE OBSERVED IN THE ATMOSPHERE?

WHY

IS OZONE OBSERVED IN THE ATMOSPHERE?

A great many replies may be found to this query, which is considered under two heads:—

1. Why has Ozone been observed?
2. Why should Ozone be observed?

1. Why has Atmospheric Ozone been observed?

The source or sources of atmospheric Ozone, and its mode of production, have always been deeply interesting and important problems which have only undergone partial solutions. Electrical storms were at one time conceived to be its sole means of origin. Dove thought that Ozone is generated in the higher regions of the atmosphere, during the condensation in their polar course of the heated equatorial currents. Many consider that Ozone is alone produced by electrical discharges which are continually occurring in the air. Dr. Moffat thinks that Ozone is produced in nature as a result of phosphorous oxidation, and that the source of Ozone is to be found in the phosphorescence of the ocean. He states that the results of observations taken during four passages across the North Atlantic show that phosphorescence of the sea and Ozone periods occur together, and that, when the sea is not phosphorescent, Ozone is at zero.

Sources.

(*a*) Phosphorescence of the sea.

The phosphorescence of the sea has been repeatedly shown ever since the years 1749 and 1750, when Vianelli and Grixellini discovered the Nereis noctiluca in the waters of the Adriatic, to depend on the presence in it of certain living animal organisms, such as Medusæ, Noctilucæ, Polypes, Infusoria, Lumbrici, and Crustaceans.

Professor Panceri.

Professor Panceri of Naples has recently ascertained that the phosphorescence of these animals is due to matter cast off by them. It is a property of dead separated matter, and not of the living tissues. In nearly all cases he finds that this substance is secreted by *glands* possibly possessing this special function. More probably the phosphorescence is a secondary property of the secretion. This secretion contains epithelial cells in a state of fatty degeneration. These fatty cells, and the fat they give rise to, are phosphorescent. He regards this phosphorescence as the result of the formation in decomposition of a phosphoric Hydrocarbon. If the surface of a dead fish which is phosphorescent be scraped, and the matter thus removed be examined microscopically, fat in a fine molecular state of division is alone visible. "Phosphorescence is prevented by the presence of fresh water; Oxygen, on the other hand, strengthens the phenomenon."[1] Analyses of sea water do not prove the presence in it of Phosphorus or any compound of this metalloid.

Noctilucine.

Dr. Phipson calls this substance "Noctilucine," an organic body that absorbs Oxygen and disengages Carbonic Acid. He asserts[2] that the emission of light is due to its oxidation in contact with damp air, and that its increased luminosity during the prevalence of S.W. winds is dependent on the large amount of Ozone which these equatorial currents contain.

Scoutetten.

Scoutetten has pointed out[3] that Ozone may be produced—

(*b*) Water.

1. By the electrization of Oxygen which escapes from water under the influence of light and air;

2. By the electrization of Oxygen secreted by plants

3. " " " disengaged in chemical action; and,

4. By electrical phenomena acting on the Oxygen of the atmosphere.

[1] *Memoir on Phosphorescence of Fish*, presented to Association of Naturalists and Physicians at Turin.

[2] "Sur la Noctilucine"—*Compt. Rend.*, August 26, 1872.

[3] *Op. cit.*

From a series of experiments varied and frequently repeated he is of opinion, and his views are supported by M. Ch. Brame,[1] that plants as well as water furnish the air constantly with Ozone during the day; that this phenomenon ceases during the night, and is suspended when they are removed from the action of direct light. He believes that the Oxygen dissolved in natural waters becomes electricized by a chemical reaction, when the water is vaporized and abandons the salts that it holds in solution. He found that distilled water, from which all air had been expelled by boiling and was afterwards excluded, did not yield Ozone.

(*c*) Vegetation.

Experiments of M. Cloez.

M. S. Cloez denies[2] that the Oxygen evolved by the leaves of plants when exposed to the sunlight undergoes any ozonisation, and that the Iodized Starch tests are thereby tinted. He suspended in a bell-glass two test-tubes, one of which was covered with black japan to exclude all light. A test being inserted in each tube, the bell-glass was placed over a growing non-aromatic plant which stood on a tuft of grass, on damp cotton, or on a plate covered with a slight layer of water. The whole was exposed to a strong light. The test in obscurity did not colour, whilst that in light became coloured. He has come to the conclusion that—

Light does not ozonise the air, otherwise the test enclosed in the dark tube would have been coloured;

Dry Oxygen is without action on the test-paper, even under the influence of the most vivid light;

Moist Oxygen colours it promptly when exposed to light, but has no effect on it in darkness; and, lastly,

Neither Nitrogen, Carbonic Acid (dry or damp), nor aqueous vapour have any effect on it.

The above and several other experiments detailed by him have led him to the conviction, that the coloration

[1] *L'Institut*, August 6, 1856.

[2] "Observations et Experiences sur l'Emploi de l'Iodure de Potassium comme réactif de l'Ozone,"—*Annales de Chimie et de Physique*, May 1857.

of the tests in Scoutetten's experiments was the result of a *simultaneous action of the air, of the vapour of water and of light* on the test.

Professor Rogers' experiments.

Professor W. B. Rogers has repeated many of the experiments of Cloez, and states[1] that his results are evidently not favourable to the view, which has been maintained by Scoutetten and others,—that the Oxygen evolved by growing plants is ozonised,—and would seem to confirm the assertion of Cloez, that the combined action of aqueous vapour and sunshine produces the coloration of the tests.

Notwithstanding these investigations of Cloez and Rogers, the evidence in favour of the opinion that vegetation is one of the abundant sources of Ozone is almost overwhelming.

M. Kosman's observations.

In 1862, M. C. Kosman communicated to the French Academy a series of Ozone observations, from which he drew the following conclusions:—

1. Plants evolve ozonised Oxygen from their leaves and green parts;

2. They disengage during the day ozonised Oxygen in a greater ponderable quantity than exists in the circumambient air;

3. During the night, the difference between the Ozone produced by plants and that contained in the air becomes *nil* in the case of isolated vegetation; but, where the plants grow thickly and vigorously, this Ozone is more abundant than that of the air;

4. Plants in the country evolve more Ozone during the day than town plants;

5. In the midst of towns and of a dense population, the night air exhibits more Ozone than that of the day; but, in proportion as the animal population diminishes and the vegetable kingdom predominates, the diurnal amount of Ozone increases until it exceeds that of the night; and,

6. The interiors of the corollas of plants do not evolve Ozone.

[1] *Edinburgh New Philosophical Journal*, January 1858.

Daubeny's researches.

Dr. Daubeny[1] in 1866 stated that his researches tended to show—

1. That atmospheric Ozone is almost entirely due to plants, the green parts of which generate Ozone during the day whilst emitting Oxygen; and,

2. That flowers generate no Ozone.

Opinion of Lawes, Gilbert, and Pugh.

Lawes, Gilbert, and Pugh, believe[2] "that the Ozone said to be observed in the vicinity of vegetation is due rather to the intense action of the Oxygen of the air upon minute quantities of volatile Hydrocarbons evolved by the plants than to any action within the cells."

Mantegazza on essences and flowers.

The investigations of Professor Paolo Mantegazza[3] of Pavia, "On the action of Essences and Flowers in the Production of Atmospheric Ozone, and on their Hygienic Utility," which he recently reported to the Institute of Lombardy, demonstrate that the disciples of Empedocles were not in error when they planted aromatic and balsamic herbs as preventives of pestilence. Herodian[4] (as Dr. Rumsey points out) has recorded that "in a plague which devastated Italy in the second century, strangers crowding into Rome were directed by the physicians to retreat to Laurentum, now San Lorenzo, that, by a cooler atmosphere and *by the odour of laurel*, they might escape the danger of infection." Can the scent of herbs and flowers do more than conceal the presence of infectious, which are generally associated with offensive, matters in the air? Mantegazza states that a large quantity of Ozone is discharged by odoriferous flowers, but that flowers destitute of perfume do not produce it. He found that in some plants Ozone is only developed by the direct rays of the sun, whilst in others the action, if commenced in solar light, continues in darkness. Cherry-laurel, clove,

Odour of laurel in plague.

[1] *Brit. Assoc. Rep.*

[2] "On the Sources of the Nitrogen of Vegetation, with special reference to the question whether Plants assimilate free or uncombined Nitrogen:" *Journ. Chemical Society*, vol. i. 1863, p. 100.

[3] *Rendiconti del Reale Instituto Lombardo*, vol. iii. fasc. vi.

[4] *Langius Fo. Florilegium Morbus*, p. 1854: Lugduni, 1648.

lavender, mint, lemon, fennel, etc., are plants which develope Ozone largely on exposure to the sun's rays. Amongst flowers, the narcissus, heliotrope, hyacinth, and mignonette are conspicuous; and of perfumes similarly exposed, eau-de-Cologne, oil of bergamot, extract of millefleurs, essence of lavender, and some aromatic tinctures. He points out that the oxidation of the essential oils, such as nutmeg, aniseed, thyme, peppermint, etc., under the influence of light and air, is a convenient source of Ozone, as they even in small quantities ozonise much of the atmospheric Oxygen. He concludes that the ozonogenic properties of flowers reside in their essences, the most odoriferous yielding the largest amount of Ozone. The Professor recommends the cultivation of herbs and odorous flowers in marshy districts and in places infected with animal emanations, and that persons who live in such situations should perfume themselves with odoriferous essences. The cultivation of the sunflower in malarious districts has been especially urged, as it is said to possess the property of purifying air laden with marsh miasm, and of exhaling ozonised Oxygen. Snuff-takers will be interested in the statement that the aroma of powdered tobacco snuff developes Ozone. Hence Dr. J. Murray regards snuff as a disinfectant.[1]

Perfumes.

Cultivation of the sunflower in malarious districts.

Snuff.

The ancient custom amongst physicians of furnishing the handles of their canes with vinaigrettes, the fumes of which might protect them from the noxious exhalations of their patients; and the old practice of strewing aromatic herbs, such as rue, before filthy prisoners, in the dock of a criminal court, so that the olfactory nerves of the lawyers might be offended as little as possible; as well as that of providing the chaplain with a bouquet when accompanying a criminal to Tyburn:—lose their absurdity under the light of these investigations. The efficacy of certain perfumes in warding off disease during exposure to fœtid air, which was thoroughly believed in by our ancestors, may be perhaps explained by the researches above referred to.

Physicians' vinaigrettes.

The strewing of rue.

The chaplain's bouquet.

Ozone has been said also to be produced during the

[1] "On Snuff-taking."

growth of mould; and during certain chemical processes of slow oxidation which are incessantly proceeding on this globe.

In looking for the sources of atmospheric Ozone, we cannot refrain from reflecting on the numerous ways in which atmospheric Electricity originates, for the development of the former is intimately connected with the production of the latter. Faraday[1] has shown that the friction of water-drops against all bodies, and therefore in all probability against air, developes in the substance rubbed a most powerful charge of Negative Electricity. Armstrong's experiments prove that the friction exerted by liberating jets of condensed air under a high pressure is sometimes sufficient to furnish sparks of Electricity $\frac{1}{4}$ inch in length.

(d) Atmospheric electricity.

Volta long ago demonstrated that Negative Electricity may be produced by allowing the fine spray of a fountain to fall on the plate of a straw electroscope. Tralles, and subsequently Humboldt,[2] observed that the spray of a descending waterfall or a lofty cascade fills the air in its neighbourhood with Negative Electricity, which may be detected by means of a delicate electrometer even at a distance of 300 or 400 feet. Belli points out that the cascade is negatively electrified above and positively below; and that the Positive Electricity passes into the earth, whilst the Negative remains united to the drops.

As electrical discharges are incessantly occurring around us, the supply of Ozone is constantly maintained, and, even close to the earth where the consumption is the largest, nearly always exceeds the demand.

Whether the force of the wind is in any way connected with the generation of Ozone, by the attrition of the particles of air against each other, has not yet been determined. M. C. Saintpierre[3] informs the French Academy

(e) Force of the wind?

Blowing machines and ventilators.

[1] *Philosophical Transactions*, 1843.

[2] *Cosmos.*

[3] "Sur la Production d'Oxygène Ozoné par l'action mécanique des appareils de Ventilation:" *Compt. Rend.*, February 29, 1864.

that he has ascertained that Ozone is developed by the mechanical action of blowing machines and ventilators producing strong currents. He considers that this fact may, in part, account for the healthy action of winds.

Summary of sources.

The oxidation of metals, the decomposition of rocks, the germination of seeds, the growth of plants; the falling of dew, rain, hail and snow; the collision between air-currents of different degrees of humidity proceeding from opposite quarters with one another or with the earth; the evaporation which is continually proceeding from saline fluids, such as oceans, seas, and lakes; the dashing and splashing, the smashing and crashing, of the restless waves on the rocky coast,—are all concerned in the simultaneous development of Electricity and Ozone.

Ozone is doubtless a constant component of pure air in small proportions, like Carbonic Acid. The amount of it present in the atmosphere at different parts of the earth's surface is very variable; its development being probably dependent on temperature, relative dryness, solarization, electricity, and other physical conditions which are perpetually changing. Storms, tempests, hurricanes, water-spouts, and other great atmospheric commotions, which bring such misery and ruin on mankind, are agents in the Creator's hand for the purification of the mighty medium in which we dwell.

Ozone being not only a powerful oxidizing but also a deoxidizing agent, it was anticipated that its varying proportions in the air would be found to have a decided influence on the prevalence and rarity of certain diseases.

Influence in health and disease.

Its presence in moderate quantity is generally considered to be an essential condition of health, and has been said to improve digestion and nutrition. The members of the Scottish Meteorological Society, who carried out a series of observations in one of the suburbs of Edinburgh, observed that the largest quantities of Ozone were obtained "when the air had a pleasant sharpness to the feelings, exercising, as it were, a stimulating influence on the spirits. When, on the other hand, the air was close and seemed to exert

a slightly depressing effect, little, if any, Ozone was detected." Air which is fresh, invigorating, crisp, enlivening, and vivifying, bearing a resemblance to mountain air, or that which we inhale after a fall of snow, has, according to my experience also, appeared to contain the largest quantity of Ozone and the other air-purifiers. The depressing influences to which residents in cities and towns are conscious of being exposed, are attributed to the absence of Ozone. Ozone has been said to be deficient during the presence of some diseases, and in excess whilst other maladies have been general. The power of arresting infection and of destroying the germs of epidemic disease has been attributed to it. Dr. Tripe, on the other hand, declares that Ozone is frequently absent when the public health is in a satisfactory state. He states that during seven weeks of the quarter ending January 2, 1858, no Ozone was present at Hackney, and yet there was no disease prevalent throughout that period; indeed, the mortality for Hackney was below the average, whilst that for all London was nearly 5 per cent in excess.

Schönbein's views.

Schönbein[1] expressed his belief that a deficiency of Ozone, or an excessive production of miasmatic matters, in the atmosphere, favours the propagation of epidemic diseases, and mentions in corroboration of this view the fact that Ozone is most abundant in winter, when zymotic diseases are least plentiful. It must, however, be remembered that chemical changes are less active during this season in consequence of its low temperature. His opinion was strengthened by the recollection that the air of the loftiest mountains, where these diseases are scarce, is more ozoniferous than that at the sea level, where they are certainly more abundant. Before attributing to Ozone any influence on the ravages of epidemic and endemic disease, it must be shown that Ozone affects the poisons that generate them. Ozone will, we know, destroy noxious odours, but there is no proof that putrescent

[1] *On some Secondary Physiological Effects produced by Atmospheric Electricity.*

emanations *per se* can produce a disease. A stench *may* or *may not* contain a subtle poison capable of multiplication in a body predisposed to receive it, by offering to it a soil adapted to its increase.

CHOLERA and DIARRHŒA.

According to Glaisher,[1] Moffat,[2] Hunt, and others, the occurrence of cholera and choleraic diarrhœa is coincident with an absence or diminution of Ozone, and their departure with a return of Ozone.

Glaisher's "blue mist."

Glaisher observed that the three visitations of cholera in 1832, 1848-9, and 1853-4, were all attended by a peculiar state of the atmosphere, which was characterized by a stagnant, dense "blue mist," by an absence of rain, of wind, and of Ozone, by a temperature above the average, and by great barometric pressure. The first decline of the disease was marked by a decrease in the readings of the barometer and thermometer. A cholera epidemic has been observed to diminish when heavy and continuous rains have washed out of the air its sewage, and to disappear when a storm or gale of wind has purified the stagnant and poisonous atmosphere. Cholera has been found to decrease, and Ozone to increase, with elevation above the sea level.

Experience of Indian medical officers.

Indian medical officers have given similar accounts of the state of the weather during the outbreaks which have occurred in their experience.

Comparative observations in London.

During the cholera season of 1854, Mr. Glaisher organized an extensive series of observations on Ozone throughout London. On making a careful comparison between these observations and the returns of mortality for the respective districts, he was astonished on finding that, where the test-papers had shown no ozonic reaction, there had been no deaths from cholera; that, on the contrary, where the tests had shown the characteristic ozonic reaction, cholera had been most active and its victims numerous.

[1] *Report on the Meteorology of London during the epidemic of Cholera in* 1854.
[2] *On Meteorology in relation to Epidemic and Sporadic Cholera.*

Dr. Moffat's observations.

Dr. Moffat states, that the meteorological conditions of a choleraic atmosphere are high barometric pressure and temperature, a calm or gentle motion of the air, wind from the Northern points of the compass, and a minimum quantity or complete absence of Ozone. He writes,[1] "About the 1st of September 1853, cholera appeared in Newcastle. On the 20th the number of deaths were,—cholera 108, and diarrhœa 10. On the 19th the south or ozoniferous current of air attended by low pressure, high temperature and luminosity of Phosphorus—the atmospheric conditions accompanying a maximum of Ozone—set in and continued. On the 28th the number of deaths reported in the *Times* was,—cholera 18, diarrhœa 2. From September 1st to 19th the mean quantity of Ozone was scarcely 1·0 of my scale; but from the latter date to the end of the month it ranged from 3 to 8 daily. The epidemic in London in 1854 disappeared with the setting in of similar atmospheric conditions."

Epidemic of 1853.

Epidemic of 1854.

TABLE 19.

NEWCASTLE, 1853.

Mean Weekly Reading of Barometer.			Mean Weekly Temperature.		Mean Degree of Humidity.		Daily Mean of Ozone.			Mean Direction of the Wind.			
No Cholera.	Cholera Increasing.	Cholera Declining.	Cholera Increasing.	Cholera Declining.	Cholera Increasing.	Cholera Declining.	No Cholera.	Cholera Increasing.	Cholera Declining.	Cholera Increasing.		Cholera Declining.	
										N.	S.	N.	S.
29·398	29·812	29·609	55·4	54·8	82	82	4·7	1·3	5·6	9	6	3	11

Choleraic Diarrhœa.

He has noted also a marked decrease in the quantity of Ozone during the prevalence of choleraic diarrhœa in the autumn months. The results contained in the following table are deduced from the observations of ten years.

[1] *Lancet*, September 9, 1865.

TABLE 20.

Months.	January, February, March.	April, May, June.	July, Aug., September, October.	November, December.
Mean number of Cases of Choleraic Diarrhœa .	8·8	8·5	13·5	7·3
Mean of Ozone . .	2·0	2·0	1·0	2·0

Epidemic of 1866.

He adds, "In the months of July, August, and September of 1866, cholera was diffused over nearly every county in England and Wales, and it destroyed 10,365 persons; and in the quarter ending December 31st the deaths from it were 2465. During the former quarter atmospheric Ozone was below the mean in Great Britain and Ireland and in the Channel Islands, and during the latter quarter it increased much in quantity. Taking the mean daily quantity of Ozone for three years, for the quarter ending September, in Great Britain and Ireland and the Channel Islands, we find that it is 4·5, while for the same quarter of 1866 it is 3·0 only; so it would appear that the diminution of Ozone was general over the country while the epidemic lasted." !!!

TABLE 21.
1866.

Mean Reading of the Barometer.			Mean Temperature.		Daily Mean of Ozone.			Daily Mean of Ozone. Ireland, Cumberland, and Flintshire.			Mean Direction of the Wind.						Mean Weekly Number of Days of Haze.		
											No Cholera.		Cholera Increasing.		Cholera Declining.				
No Cholera.	Cholera Increasing.	Cholera Declining.	Cholera Increasing.	Cholera Declining.	No Cholera.	Cholera Increasing.	Cholera Declining.	No Cholera.	Cholera Increasing.	Cholera Declining.	N.	S.	N.	S.	N.	S.	No Cholera.	Cholera Increasing.	Cholera Declining.
29·611	29·754	29·617	57·6	52·0	2·3	0·9	1·4	4·0	1·7	3·6	0·6	6·0	3·8	3·1	1·3	4·8	0·0	3·3	1·3

These results show that the atmospheric conditions during the progress and decline of the epidemic of 1866 were similar to those of former epidemics.

Dr. Moffat also noticed, during a period of two years, that 60 per cent of cases of sporadic cholera occurred at the same time as the issuing of Admiral Fitzroy's storm telegrams.

Dr. Cook and the Presidency of Bombay.

In the report on the registration of Ozone at the several stations of the Bombay Presidency, for the years 1863 to 1868, by Dr. Cook, it is stated that,[1] "although in many of the stations the presence of cholera was marked by an almost total absence of Ozone, in the majority of cases it was a *relative* deficiency that was most apparent, *i.e.* a decrease of Ozone numbers below the level of the normal quantities of those particular periods."

Dr. Smallwood and Canada.

Dr. Smallwood, after making a long series of observations in Canada during the prevalence of cholera and at other times, was inclined to the belief that a deficiency of Ozone existed during the epidemic.

M. Fournet and Lyons.

M. Fournet affirms that in Lyons, the "city without Ozone," cholera is not more frequent or severe than elsewhere.

Professor Peter and Lexington, U.S.

Some American physicians made some Ozone observations during the epidemic of cholera which visited the United States in 1851. Professor Peter conducted experiments at Lexington from June 30 to August 12, being nearly the complete period during which the cholera prevailed there. He arrived at these conclusions—

(1.) That there was no constant relation between the amount of Ozone and the number of deaths;

(2.) That the indications of its presence did not cease with the accession of cholera; and,

(3.) That the principle which discolours the test appeared to be rarely absent from the atmosphere.

Seitz of Munich.

Seitz writes[2] thus concerning the cholera epidemic of 1854 in Munich:—"I could notice during the whole continuance of the epidemic no relation between the increase and decrease of the same in connection with the amount of Ozone in the air. In August, with a large amount of Ozone, this disease increased from day to day; whilst in September, with a small amount of Ozone, it decreased."

[1] *Brit. Assoc. Report*, 1869.
[2] *Catarrh und Influenza*, 1865.

Father Denza of Moncalieri, near Turin.

During the autumn of 1867, when cholera was severe at Turin, Father Denza made electrical and Ozone observations at Moncalieri, near this city.[1]

TABLE 22.

MEAN VALUES of ELECTRICITY and of OZONE observed at MONCALIERI, from August 21 to September 10, 1867, during the height of a Cholera Epidemic.

Days.	AUGUST.			Days.	SEPTEMBER.		
	Electricity, observed every 3 hours.	*Ozone*, observed every 3 hours.	*Ozone*, observed every 6 hours.		*Electricity*, observed every 3 hours.	*Ozone*, observed every 3 hours.	*Ozone*, observed every 6 hours.
21	8·1	2·8	3·5	1	0·5	2·3	4·1
22	5·0	3·5	5·3	2	1·6	2·1	3·3
23	21·8	4·8	6·0	3	2·2	2·7	3·9
24	9·1	4·9	5·3	4	0·0	3·4	4·7
25	0·1	3·2	4·5	5	0·1	3·2	4·8
26	0·0	4·3	5·3	6	0·1	3·0	4·3
27	13·4	4·5	5·8	7	5·2	2·6	4·5
28	18·7	5·1	5·9	8	7·0	3·3	5·2
29	0·1	2·6	4·0	9	9·2	1·5	4·1
30	0·0	1·0	3·8	10	9·0	2·8	5·2
31	0·3	2·9	3·5	...	...	...	...

Electricity was entirely or almost wholly wanting from August 25 to September 6 (days when cholera was worst at Turin). After September 6 it resumed its regular course. The very strong values of August 27 and 28 are attributable to storms which occurred on these days. Ozone diminished after the 28th, but in a manner much less sensible and more uncertain.

Dr. Day of Geelong.

Dr. Day of Geelong assures me that he suspended ozonoscopes around the houses of patients suffering from

[1] "Note sur les valeurs de l'électricité de l'Ozone observées à Moncalieri dans le temps du Cholera:" *Compt. Rend.* January 13, 1868.

cholera in December 1865, and noted an abundant ozonic reaction.

Dr. Conraux and Thann.

The disappearance of Ozone from the air during a cholera epidemic was noticed in 1854 at Thann by Dr. Conraux, whilst ozonoscopes simultaneously coloured at villages situated at $1\frac{3}{4}$ mile from the town, to which the disease had not spread.

Dr. T. Boeckel of Strasburg.

Dr. T. Boeckel of Strasburg made Ozone observations in that city during the cholera epidemic of 1854, and noticed a certain diminution of Ozone during the days on which the epidemic attacked the greatest number of people.

TABLE 23.

OZONE and CHOLERA at STRASBURG in 1854.

Date.	Number of Cases.	Number of Deaths.	Mean of Ozone for 24 Hours.
From the 10th to the 20th of July . .	6	3	5·4
" 21st " 31st "	148	44	2·1
" 1st " 10th of August .	284	86	2·8
" 11th " 20th "	171	74	2·6
" 21st " 31st "	160	67	1·83
" 1st " 10th of September	191	100	6·6
" 11th " 20th "	108	39	4·0
" 21st " 30th "	35	29	4·1
" 1st " 10th of October .	16	9	3·5
" 11th " 20th "	15	9	6·7
" 21st " 31st "	4	2	7·17
" 1st " 10th of November	2	2	5·0
Total . . .	1140	464	

Dr. E. Boeckel of same city.

The observations of Dr. E. Boeckel,[1] however, have led him to conclude that there is no connection between the progress of this disease and the ozonometric indications. "The minimum of Ozone does not coincide with the maxi-

[1] *De l'Ozone*, 1856.

mum of cholera, and this last does not diminish in proportion as the Ozone augments."

Dr. Robert of Neudorf.

The observations of Dr Robert,[1] at the village of Neudorf, during a brief cholera epidemic, are favourable to the view that a relation does exist.

M. Simonin of Nancy.

Mons. Simonin senior remarked the coincidence of the appearance of cholera at Nancy in 1854 with a "No Ozone period," but did not observe a similar agreement during the epidemic of 1855.

Strambio of Milan.

Strambio made an extremely careful series of observations at Milan during the cholera epidemic of 1855. He not only exposed Schönbein's tests during each period of twelve hours, but made observations every three hours. He declares that the quantity of Ozone in the air did not diminish as the cholera increased in severity, and *vice versâ*. Nor did the monthly totals exhibit any marked diminution in test-reaction during August and September when the epidemic was at its height.

[1] *Gaz. Méd. de Strasbourg*, Nov. 1855

TABLE 24.

Date.		Cholera Morbus.				Atmospheric Ozone.		
1855.		Milan.		Corp. Sant.				
Month.	Day.	Cases.	Deaths.	Cases.	Deaths.	8 A.M.	11 P.M.	Mean.
August .	21	10	11	13	6	3	4	3·50
	22	12	9	10	10	3	4	3·50
	23	9	7	10	13	4	5	4·50
	24	23	11	5	6	5	5	5·00
	25	18	9	5	3	3	6	4·50
	26	17	15	12	7	5	5	5·00
	27	15	7	4	5	4	7	5·50
	28	30	19	8	6	4	3	3·50
	29	33	21	16	10	5	6	5·50
	30	37	23	18	13	5	6	5·50
	31	19	17	18	11	2	7	4·50
September	1	42	25	4	7	6	7	6·50
	2	37	22	15	7	7	9	8·00
	3	34	22	8	6	8	5	6·50
	4	45	27	15	11	7	7	7·00
	5	49	31	15	6	6	5	5·50
	6	50	24	9	6	8	6	7·00
	7	39	41	12	12	4	3	3·50
	8	61	42	10	6	3	0	1·50
	9	72	52	9	10	1	4	2·50
	10	52	38	19	17	1	4	2·50
	11	43	36	10	9	9	7	8·00
	12	49	30	13	6	2	8	5·00
	13	49	31	15	5	9	8	8·50
	14	25	35	9	10	6	8	7·00
	15	26	21	13	5	0	7	3·50
	16	27	21	18	9	9	7	8·00
	17	34	22	4	3	7	5	6·00
	18	16	25	9	8	6	6	6·00
	19	11	19	3	3	9	9	9·00
	20	15	15	7	3	0	6	3·00
	21	10	19	5	4	0	8	4.00
		Monthly Totals.						
July		11	4	8	4	5·00	5·18	5·09
August . . .		429	279	249	168	4·68	5·22	4·95
September . .		378	673	252	197	4·93	6·20	5·56
October . . .		60	54	52	48	6·61	6·31	6·46
November . .		21	11	4	4	4·50	4·73	4·61

At Berne, a very decided diminution in the amount of ozonic reaction was noticed by M. Wolf in the middle of September 1845, at a time when cholera prevailed in Switzerland. M. Wolf of Berne.

At Marseilles, a complete absence of Ozone in the air has been recorded during cholera epidemics. Marseilles.

At Berlin, a subsidence and reappearance of cholera has been found to coincide with the presence and absence of Ozone. Berlin.

A number of pamphlets have appeared, regarding the supposed relationship between cholera and Ozone, at Munich by Pettenkofer,[1] at Königsberg by Schieffer-decker, at Vienna, Cracow, at Szegedin in Hungary, at Senftenberg in Bohemia, at Kremsmünster, etc. They are all unfavourable to the hypothesis that Ozone descends below its summer minimum during an epidemic. Other stations.

Dr. Billard of Corbigny is of opinion that the diminution of Ozone in the atmosphere is the first cause of cholera, and that this modification of the air brings forth a change in the animal organization, in consequence of which the liquids enclosed in certain vessels, and the substances contained in the digestive tube, are withdrawn from vital action, and only remain subject to the forces by which inert matter is ruled. Dr. Billard's opinions.

As regards simple diarrhœa, Dr. Moffat found that there is a decrease in the readings of the barometer on the day on which diarrhœa occurs, and on the day after it; and that there is an increase in the quantity of Ozone, and in the force of the wind, on these days. Simple diarrhœa.

[1] *Ueber die Cholera*, 1855.

TABLE 25.

Highest and Lowest Readings of Barometer.			Mean of Ozone.			Mean Force of Wind.		
Highest Day before Diarrhœa.	Lowest Day of Diarrhœa.	Lowest Day after Diarrhœa.	Day before Diarrhœa.	Days of Diarrhœa.	Day after Diarrhœa.	Day before Diarrhœa.	Days of Diarrhœa.	Day after Diarrhœa.
29·724	29·635	29·599	1	2	1	1·0	2·0	1·6

After weighing all the evidence *pro* and *con* the presumed relationship between cholera and Ozone, and coupling it with my own experience, I am of opinion that we cannot at present come to a conclusion more definite than the following:—

Conclusion regarding cholera.

That, if Ozone is absent or diminished in amount during cholera epidemics, its absence or deficiency would appear to be occasioned by the simultaneous occurrence of those atmospheric conditions which characterize "no Ozone periods" or "minimum Ozone periods;" and by an increase in the amount of organic matters, which are invariably noticed in air vitiated with the emanations of the sick and diseased. The greater quantity of Ozone at elevated than at low-lying cholera stations is doubtless due to the increased movement of the air in the former localities, and to the consequent accumulation of a smaller amount of organic impurities, in the oxidation of which Ozone is consumed.

CATARRH and INFLUENZA.

As a disease analogous to if not identical with catarrh may be excited by making an animal breathe air containing an excess of Ozone artificially prepared, Schönbein surmised that epidemics of influenza might be produced by a redundance of this body in the air. He and other physicians accordingly made daily atmospheric Ozone observations[1] during several catarrhal epidemics

[1] Henle und Pfeufer's *Zeitschrift für rationelle Medizin*, Bd. vi. Heft 2.

at Basle, which are stated to have been conclusive as to the simultaneity of the maximum of the coloration with the extreme intensity of the epidemic.

Observers at Basle.

Dr. Seitz of Munich.

Dr. Seitz carried on a number of observations with Schönbein's tests in Munich, the results of which he compared with the occurrence of catarrhal diseases of the respiratory organs.

OBSERVATIONS at MUNICH[1] from March 1853 to March 1855.

	Ozone.	Catarrh of Respiratory Organs.
1853.		
March . .	Increase . .	Diminution. Cases of Intestinal Catarrh and Typhus Fever noted.
April 8th to 13th. Strong W. wind, rain, and snow.	Great deal . .	Very few cases.
From 21st to end of month	Large amount .	No spread of the disease.
1854.		
March . . / April . . / May . .	Very little . .	A number of cases occurred.
June . .	Increase . .	Decrease.
On June 11, the max. of the year was noted = 10 with a clouded sky and W. wind	Maximum . .	No cases.
August . .	Large amount	None.
September .	Little . . .	Cases reappeared.
October . .	Increase . .	Only a few cases.
November . / December .	Considerable amount	Moderate number.
1855.		

The winter months of this year showed no agreement between the amount of Ozone and the number of cases of influenza.

Seitz writes, "We found that months in which the

[1] *Op. cit.*

Ozone was abundant were not characterized by a predominance of catarrhal affections, when compared with months during which less Ozone was noticed in the air. After days distinguished by a great excess of Ozone, we did not observe the occurrence of a greater number of cases of catarrh."

He thinks that cold and wet have more to do with the etiology of influenza than any other atmospheric conditions.

A negative result followed also the observations as to the amount of Ozone in the air, and its relation to the prevalent diseases, conducted during the year 1856 by the Medical and Scientific Club of Königsberg in Prussia. They showed—

Observers at Königsberg.

1. That the month of November, during which the spread of catarrhal affections was most extensive, and the month of September, which was notorious for the prevalence of intermittent fever, typhus, cholera, and diarrhœa, exhibited nearly an equal amount of Ozone;

2. That a sudden and considerable increase in the amount of Ozone did not appear to be a cause of the commencement of catarrh of the respiratory organs; and,

3. That there was no connection at any time between a malady and the amount of Ozone to be found in the air.

Dr. Pfaff of Plauen.

Dr. Pfaff, who has made observations on the influence of Ozone on diseases at Plauen, in Saxony, concludes[1] that—

1. A large proportion of Ozone in the air acts in a mischievous manner on diseases of the respiratory organs;

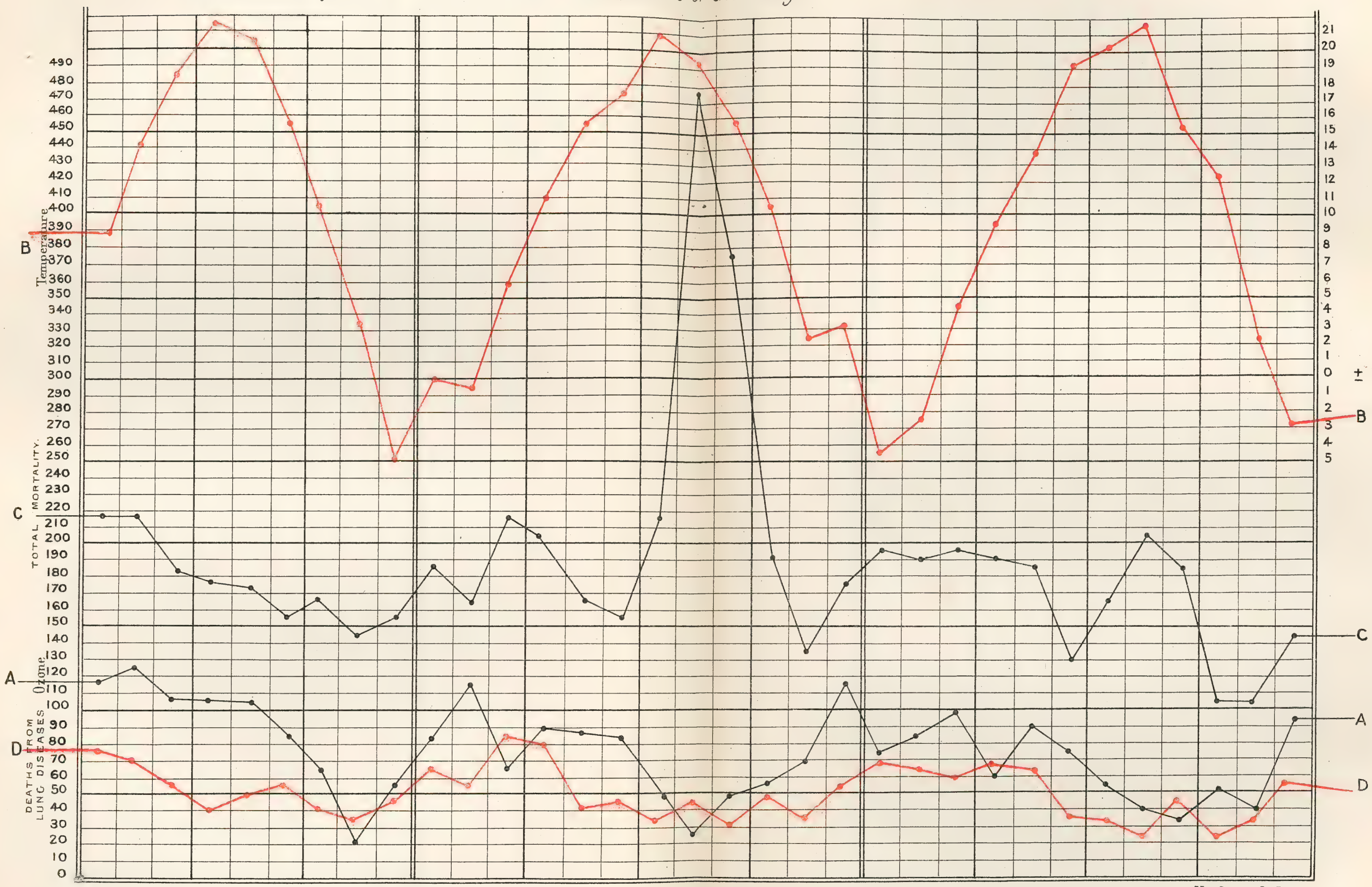
2. A large amount of Ozone in the air, whatever may be the direction of the wind, favours the development of inflammatory affections, and especially tonsillitis; and,

[1] Henke, *Zeits. für Staats*, 1862, No. 2.

TABLE 26.

Comparison between the Ozone, the Temperature and the Mortality of Strasburg during 1853-1855.

Curve A, Ozone per 24 Hrs. indicated in tenths. Curve B, Temperature (Cent.) 0 of this scale corresponds with the line 300. Curve C, Deaths generally. Curve D, Deaths from diseases of the Lungs.



Hanhart. lith.

3. The Ozone of the air exerts little or no effect on epidemic or other diseases, provided they are not complicated with catarrhal affections.

Dr. Ireland and Bengal.

Dr. Ireland noted at the hospital of Umballa, Bengal, that a sudden decrease in the amount of Ozone was followed by a threefold increase in the number of patients, and by the prevalence of rheumatism and influenza; and that, when there was an increase of ozonic reaction, the patients recovered.

Dr. Spengler of Roggendorf.

Dr. Spengler[1] calls upon the medical practitioners of Europe to test the accuracy of his observations, which were made at Roggendorf, a village of Mecklenburg. Just before the commencement of an epidemic of influenza no Ozone was to be detected. Directly, however, catarrhal affections set in, and every one was coughing, an abundance of Ozone was manifested. As the disease gradually diminished, so did the indications of this body decrease.

Dr. Heidenreich.

Dr. Heidenreich also found that a strong ozonic reaction coincided with an exacerbation of catarrhal symptoms and the appearance of pulmonary affections, while a diminution of these took place when it was feeble.

Other observers.

Faber, Wunderlich, Schiefferdecker, T. Boeckel, and other observers, believe that there is no connection between the development of Ozone and the prevalence of catarrhal affections.

Dr. E. Boeckel's comparative observations at Strasburg on the Ozone, temperature, and mortality.

Dr. E. Boeckel, having made a careful comparison between the Ozone observations conducted at Strasburg and the number of cases of disease occurring there during each month of the years 1853, 1854 and 1855, is of the opinion that the influence of Ozone on the production and aggravation of pulmonary affections is beyond a doubt, and is greater than that of temperature. (*Vide* Table 26.)

Metz.

The authorities at the hospital of Metz have found that there is a certain relation between the variations in the quantity of atmospheric Ozone and the number of cases of bronchial affections which present themselves.

[1] Henle und Pfeufer's *Zeitschrift*, vol. vii. p. 70.

Houzeau and Leudet's comparative observations at Rouen.

The following table, arranged by MM. Houzeau and Leudet jun., shows that there is no agreement between the prevalence of respiratory affections at Rouen and the depth of ozonic reaction as presented by *true* Ozone tests. These diseases are most numerous during the winter, when the amount of Ozone, as distinguished from the other air-purifiers, would seem from the researches of the former gentleman to be comparatively small.

TABLE 27.

Table of Comparison between the number of Cases of Affections of the Lungs and the Days distinguished by a manifestion of Ozone at Rouen during the years 1861-64.

Seasons.	1861.		1862.		1863.		1864.	
	Cases of Pneumonia and Bronchitis.	Days of Ozone.	Cases of Pneumonia and Bronchitis.	Days of Ozone.	Cases of Pneumonia and Bronchitis.	Days of Ozone.	Cases of Pneumonia and Bronchitis.	Days of Ozone.
Winter (Jan., Feb., and March) . .	22	27	39	26	37	19	38	15
Spring (April, May, and June) . . .	34	65	30	57	19	56	22	46
Summer (July, Aug., and September) .	7	39	5	36	9	36	3	37
Autumn (Oct., Nov., and December) .	10	15	7	21	20	14	15	22

Mr. Harris of Worthing.

Mr. Harris of Worthing informs me that he has always remarked during the prevalence of N.E. and E. winds, when no Ozone is present in the air, the great frequency of irritative affections of the mucous membrane of the throat and air-passages.

M. Bénard of Havre.

The results arrived at by M. Bénard of Havre are:—

1. That the number of cases of pulmonary disease is probably in direct relation with the amount of Ozone in the air, and in inverse relation with the temperature; and,

2. That atmospheric Ozone appears to exert a certain influence on rheumatismal affections.

Schönbein's inference was reasonable, for it would be quite impossible to distinguish between the symptoms of an over-dose of Ozone and an attack of influenza. They are similar to those produced by the vapours of diluted Chlorine or Bromine, being purely local in character.

Dr. Clemens of Frankfort.

Dr. Clemens of Frankfort states[1] that eleven saddle horses contracted inflammation of the lungs in consequence of being run against a south wind very powerful and very rich in Ozone, and that the greater number died.

Experiments of Dr. Richardson.

The experiments of Dr. Richardson[2] show that an irritation of the mucous membranes of the nostrils, throat, conjunctivæ, and even congestion of the lungs, are rapidly induced by making animals breathe air highly charged with Ozone.

Dr. Ireland's experiments.

Dr. Ireland has made many experiments[3] on animals with ozonised air. He states that—

1. "Ozonised air accelerates the respiration and, we may infer, the circulation.

2. Ozonised air excites the nervous system.

3. Ozonised air promotes the coagulability of the blood, probably by increasing its fibrine. In the blood, Ozone loses its peculiar properties, possibly entering into combination with some of the constituents of the circulating fluid.

4. Animals can be subjected to the influence of a considerable proportion of Ozone in the air for hours without permanent injury; but in the end Ozone produces effects which may continue after its withdrawal and destroy life."

Dr. Schwartzenbach's experiments.

Dr. Schwartzenbach has also made experiments[4] on animals with ozonised air, and has arrived at similar

[1] "Wirkungen der das Ozon zerst Gase:" Henle und Pfeufer, *Zeitschr.*, B. vii. H. 2.

[2] "On Physiological Experiments with Ozone:" *Brit. Association Adv. Science Report*, 1865. [3] *Chemical News*, March 7, 1863.

[4] *Ueber die Einwirk des Ozons auf Thiere, Verhandl. der physik. med. Gesellsch. zu Würzburg*, B. vi. 1850, p. 322.

results. He found that if a rabbit was made to breathe air mixed with only $\frac{1}{2000}$ of its weight of Ozone, a fatal result would follow in two hours.

Professor Hoppe's experiments on animals with ozonised turpentine.

Professor Hoppe details experiments[1] on animals with ozonised Turpentine introduced into the system either by the alimentary canal or through a wound. This Ozone-carrier appears to act simply as a more powerful irritant than *un*ozonised oil.

Difference in the susceptibility of various animals to the influence of Ozone.

The existence of a remarkable difference in the susceptibility of various animals to the influence of Ozone is curious and deserves a passing reference. The effects would seem to be more developed in rats than in guinea-pigs, and in guinea-pigs than amongst rabbits. Air impregnated with only $\frac{1}{6000}$ part of Ozone is almost immediately fatal to mice. Pigeons appear to exhibit a greater tolerance, whilst frogs seem to be able to resist completely the action of Ozone, provided they are supplied with water. That birds should resist more than other animals the influence of a highly ozonised atmosphere is not surprising, destined as they are to live in the upper regions of the lowest stratum of air, where Ozone is more abundant than on the surface of the earth.

Conclusion regarding Catarrh and Influenza.

The evidence in favour of the supposed connection between influenza and an excess of atmospheric Ozone is far from being decisive, for this disease is sometimes prevalent during periods when Ozone is not observed to be in excess.

Dr. Richardson thus points out[2] the stage at which our knowledge has arrived with regard to this question:—"We must yield that Ozone in excess, as we produce it in the laboratory, induces certain symptoms of disease; but as yet we know of no instance in which an excess sufficient to produce the same symptoms exists in nature. An air so charged with Ozone as to produce these symptoms

[1] *Wunderlich's Archives*, 1848.
[2] *Popular Science Review*, January 1866.

would require no chemical test to prove the presence of an injurious agent. It would be an irrespirable air, and it would affect with varying intensity all who breathed it."

Odour of Ozone is very powerful.

The odour of Ozone is so powerful, that air containing only one millionth of it is said to have a decided smell of the gas. Although atmospheric air appears to most persons inodorous, some scientific men have detected a smell in perfectly pure air analogous to that of largely diluted Ozone. We lose so readily the faculty of perceiving an odour which we have breathed for a long time, that, unless we adopt some means of suddenly bringing into contact with our olfactory nerves, which have been subjected for many hours to a vitiated atmosphere, a whiff of the purest country air, we shall not succeed in recognizing it. In the early morning, and during snowy weather, it is most striking, when we suddenly admit the country air into our bedrooms by opening the windows.

Odour of atmospheric air.

Houzeau exposed for a few hours two blankets of the same size and kind, the one to pure country air, and the other to the air of a close, inhabited room. He found that the first of the blankets suspended in the air had an odour similar to that of diluted Ozone, whilst the second remained inodorous.

He thinks it possible that the odour of normal air may be more sensitive to birds than to men, and may serve to guide them in their long migrations.[1]

Odour of sea-air.

The peculiar odour of sea-air, which is altogether distinct from that of sea-weed, is probably due to Ozone. It is readily perceived in travelling by rail from some inland place towards the coast. This same smell is noticed in the neighbourhood of the houses, at the inland station of Kissingen, devoted to the evaporation of saline springs, where the ozonic reaction is intense.

Ozone Periods and Febrile Affections.

Periods of Ozone, and seasons characterized by an increase in the amount of febrile disease, do certainly seem to correspond with each other. The apparent connection between them is supported by an assertion of Dr. Richard-

[1] *Compt. Rend.*, March 9, 1868.

son, to the effect that an increase of temperature can be induced in an animal by submitting it to the influence of Ozone at a temperature above 70° Fahr. In such a case, however, the febrile symptoms are probably induced as a result of the irritation of the bronchial mucous membrane.

The question to which we require an answer is—Is there any reason for thinking that atmospheric air ever contains enough Ozone to produce catarrhal symptoms? Although many observers—such as Scoutetten, Wood and Richardson, and myself—have experienced these symptoms during experiments in the laboratory, when the air has contained an excess of Ozone, yet no such effects are produced amongst those who breathe it freely diluted with air, when the odour is notwithstanding distinctly perceptible.

Amount of Ozone in the air.

Estimates of the amount of Ozone in the atmosphere agree in showing that it exists in such exceedingly minute quantity as to be quite insufficient to *create* symptoms of catarrh, even if the proportion were doubled or trebled. Houzeau states[1] that the air of the country, obtained from about six feet above the soil, does not contain more than $\frac{1}{450000}$ of its weight of Ozone, or $\frac{1}{700000}$ of its volume (the density of Ozone being, according to M. Soret, 1·658).

Ozone. Milligram.		Ozone. Of a grain.	Air. Litres.	Air. Cub. in.	Air. Grains.	Authority.
·02	=	(·000308)	in 255	(15,560 or	3,935,249).	Pless and Pierre.
·002 to ·01	=	(·0000308 to ·000154)	in 100	(6102·4 or	1,543,235).	Zenger.
		1 part	in	10,000 parts.		Richardson.

It has been suggested that man may be more susceptible than other animals to its influence. If such is the case, it has yet to be proved. We do not hear of sailors, who are generally immersed in highly ozoniferous air, ever suffering from an epidemic of influenza whilst at sea. Ozone is said to be exceedingly abundant in Skye, where catarrh is never observed. The large mortality from consumption in the Hebrides has been ascribed to the excess of Ozone in the air of those islands. It is quite possible that air so stimulating may still further excite lungs already irritated by the presence of tubercular matter.

[1] *Compt. Rend.*, March 11, 1872.

Haviland's investigations.

Mr. Haviland has shown[1] that, as regards heart-disease and dropsy, "wherever the prevailing sea winds have uninterrupted access, as over a flat or elevated country or up broad valleys, there we find a low mortality; and that, on the contrary, in localities where the tidal wave has no access, where the rivers run at right angles to its course, or to that of the prevailing winds, and where the districts are sheltered by lofty hills from the full sweep of the sea winds, so that the air sewage cannot be frequently removed by strongly ozonised currents, there we find the highest mortality." On the other hand, he found that the most exposed and elevated situations have the highest mortality in consumption, and that sheltered positions yield the lowest.

Pulmonary Consumption.

Air loaded with Ozone, as, for example, sea air, is probably prejudicial to *advanced* cases of consumption, attended with great frequency of the pulse and other symptoms indicative of rapid chemico-vital changes; partly on account of its irritative effects on the lung-tissue, rendered preternaturally sensitive, and partly by reason of its powerful oxidizing properties. In the early stages of the disease, before any softening or excavation of the pulmonary structures takes place, the beneficial effects of a sea-side residence are very striking. A gradual removal, by oxidation, of the effete material named tubercle, may possibly be effected by the constant contact of air containing an abundance of the most active form of Oxygen.

Conclusion respecting catarrhal affections.

The evidence which we possess warrants us in answering the question just propounded in the negative, and in adding that there is a great probability that pulmonary affections are generally aggravated by the inhalation of a highly ozoniferous air.

Rheumatism and heart disease.

The *materies morbi* of rheumatism, which is, according to Mr. Haviland's experience, the most frequent cause of the endemic heart-disease of this country, may possibly

[1] Lectures on the *Geography of Disease.*

be destroyed by Ozone. It is a remarkable fact that an accumulation of air-sewage is coincident with an excess of rheumatism and an excess of heart-disease.

MALARIA.

The observations of Clemens, Schönbein, Bérigny, Hammond, Billard, and T. Boeckel tend to show that the quantity of Ozone in the atmosphere and the prevalence of malarious diseases bear an inverse proportion; and that this is the case not only in point of time, but also in respect of locality.

Dr. T. Boeckel.

The last-named physician has observed that the malarial fevers only reign when the ozonometer indicates zero.

Dr. Gaillard.

Dr. E. S. Gaillard, an American physician, has noticed a striking relationship between the presence of Ozone in the air and the appearance of intermittent and bilious remittent fevers.

M. Wolf.

M. Wolf of Berne, who states that a rapid diminution in the quantity of Ozone is almost always followed by a considerable increase in the mortality, noted, during an epidemic of dysentery which prevailed in that city in August and September 1855, that the energy of the disease appeared to augment or diminish with the quantity of Ozone.

M. Pouriau.

M. Pouriau observed that the minima of Ozone coincided during the years from 1863-1864 and from 1864-1865 with those periods, when "les fièvres de Bresse" were most severe.

Dr. Prosper de Pietra Santa and Algiers.

Dr. Prosper de Pietra Santa states that at Algiers he has not noticed any connection between the proportions of atmospheric Ozone and the number of cases of intermittent fever or of pulmonary affections.

The malarial poison, which is regarded as a product of vegetable decomposition, is generated in greatest abundance in marshy districts, the air of which contains a considerable quantity of organic matter. Its accumulation during the night has been ascribed by Uhle to the non-production of Ozone by the sun's rays. Many believe that

Ozone is an antidote to the marsh miasm, by virtue of its supposed power of destroying organic matters present in the air. We are told that there are several kinds of organic matter contained in the atmosphere, one of which may be wholesome, another neutral, a third putrid, whilst a fourth or organized form, consisting of infinitely minute germs, is the most dangerous. Refraining from a digression with respect to the nature of the organic matter of marsh air, we learn on good authority that Ozone passed through a solution of it does not decompose it. The statement that Ozone is deficient in the air over marshes is not confirmed by the investigations of Burdel.[1] He frequently found as much Ozone in such situations as in other air.

Four kinds of organic matter in air.

Ozone not deficient in marsh air.

Dr. Clemens of Frankfort has divided stagnant water into two groups:—

Dr. Clemens' two groups of stagnant water.

1. Morasses which in sunshine emit ozonised Oxygen;
2. Stagnant water, the exhalations from which destroy the Ozone contained in the air.

He writes—"I do not wish to be supposed to imply that the first class is quite uninjurious, any more than I would be supposed to consider the disease-producing principle of the second class as referable solely and alone to the destruction of the Ozone by the emanations."

The organic matter of marsh air is in all probability not the poison itself, but merely the vehicle for its diffusion.

There is no evidence to show that Ozone destroys the marsh miasm, or is in any way related to malarious diseases. We must not, however, ignore the possibility of a connection. For centuries we have known that belts of trees, broad surfaces of water, especially salt water, curtains of moistened canvas, etc., if interposed between human habitations and the source of the malarial poison, exercise a protective influence. We have already seen that vegetation is one of the manufactories of Ozone, and that this body is also abundantly produced by evaporation from the surfaces of saline fluids freely exposed to light and air.

Conclusion respecting malarious diseases.

[1] *Recherches sur les Fièvres Paludéennes*, 1858.

Rarity of malarious diseases in towns and cities.

The rarity of malarious affections in towns and cities has been attributed by Dr. Wood to the evolution of ethereal oils in the combustion of wood and coal, by which, he states, a large proportion of Ozone is produced. M. Loew has made a similar error, which has been pointed out by Dr. Boeke, who showed that the coloration of the Iodized Starch test in such a case is due to the action of a compound of Nitrogen and Oxygen. If Dr. Wood's statement were correct, as to the production of Ozone by the combustion of fuel, the air of our most populous cities would not be generally so destitute of all traces of this body. Dr. Moffat declares that the consumption of coal is attended by the destruction, instead of the formation, of Ozone, and prevents its manifestation in the central districts of a large city, unless it be present in very unusual quantity.

Croup, Diphtheria, & Quinsy.

Some authors have argued that Ozone stands in relation to croup, diphtheria, and quinsy, in the position of cause and effects.

Affections of the Serous Membranes. Cutaneous Diseases.

Dr. Heidenreich states [1] that affections of the serous membranes—*e.g.* the arachnoid and the synovial, and various cutaneous diseases—*e.g.* nettle-rash, shingles and modified small-pox—have appeared during very feeble signs of the presence of Ozone.

Dr. Day of Australia commenced in 1864, and continued for nearly six years, observations with the view of determining whether or not atmospheric Ozone exercises any influence over health and disease. He believes that Ozone is one of the principal factors in the causation of diphtheria. The conclusions which he arrived at may be thus condensed:—

Impetigo or "native pock."

"1. That when, for several days and nights in succession, there has been an abnormal amount of Ozone in the air—that is more than 6° or 7° (Schönbein's scale) in the twelve hours—we may expect influenza, diphtheria, and an impetiginous form of skin-disease known as 'Native

[1] *Canstatt, Jahr.* 1850, vol. ii.

Pock,' to present themselves, and to prevail until the ozonic reaction has diminished. Every severe epidemic of diphtheria which we have witnessed in Geelong has been preceded by a smart epidemic of influenza.

Nettle-rash.

"2. That in cold, wet weather, when the test-coloration is deep, nettle-rash of a most troublesome character is often prevalent, particularly among the police and others who are much exposed to the air."

Small-pox.

Ozone has been observed by E. J. Lowe to be in excess, and equatorial winds to be prevalent, during months in which an epidemic of small-pox has been most virulent. In 1848 the mean daily amount of Ozone at Nottingham was during October 4·8, November 4·7, and December 11·8. The temperature of October and November was respectively 2° and 3° below the average. The greatest mortality took place in December, and was attended by an excess of Ozone, high Westerly winds, and a low barometer which was ·120 of an inch in defect of the mean of seven years.

Relapsing Fever.

Dr. Ross, medical officer of health for St. Giles', London, found that, during the recent outbreak of relapsing fever in that part of the metropolis, the amount of Ozone in the atmosphere, as indicated by the observations made at the Greenwich Observatory, decreased as the mortality from the disease increased, and *vice versâ*.

Daily Mean of Ozone.	Daily Mortality.
·4	3·4
1·0	3·0
3·0	·9
5·0	·3

Measles, Scarlatina, Typhus, & Continued Fever.

At Salford, in 1869, it was remarked that "generally, as the amount of Ozone decreased, the seizures in measles, scarlatina, typhus, and continued fever increased."

Admiral Fitzroy's storm telegrams, and diseases of the vascu-

Dr. Moffat has noticed a remarkable coincidence between the late Admiral Fitzroy's storm telegrams, Ozone periods, and the occurrence of diseases of the vascular, nervous, and muscular systems. He informs us that 80

lar, nervous, and muscular systems.

per cent of cases of apoplexy, epilepsy, and sudden death, occur on the days when phosphorus becomes luminous and there is an increase of Ozone in the air, in consequence of the setting in of a S. or S.W. gale. It is not necessary to ascribe the advent of these calamities to an increase of Ozone, for a sudden decrease in the barometric pressure is sufficient to account for the apoplexy and sudden death. Moreover, healthy people of highly nervous temperament are often sensible of a diminished pressure of the air by toothache, pains in the joints, and other nervous symptoms.

CATTLE-PLAGUE.

The generation of Ozone was thought to be below its normal standard during the period when the cattle-plague visited this country. Dr. Moffat has adduced some testimony, which seems to indicate that Ozone offers resistance to the action of the poison which produces the disease. He thus writes:[1] "In a certain locality there were four stocks, within about half a mile of each other, consisting of sixty, twenty-six, twenty-three, and twenty-two animals; the centre stock, consisting of twenty-three cattle, was disinfected. This stock was not only the last of the four which was attacked with the plague, but the disease lingered with it for seven weeks, while the other stocks were carried off in a mean period of thirteen days.

"If Ozone possesses the disinfecting properties it seems to, cattle-plague ought to have been less prevalent and fatal in the Western counties, in hilly districts, and where there are no manufactories, than in the Eastern and midland counties, in districts of low elevation, and in manufacturing districts.

"From the following numbers for the week ending March 3, 1866, it will be observed that such was the case:—

Number of cattle attacked in South-Western counties, Monmouthshire, and Wales	9,027
Number attacked in Eastern counties and in Yorkshire	40,526

[1] *On Meteorology in relation to Epidemic and Sporadic Cholera*, etc.

Number attacked in West-midland counties (inland)	10,476
Number attacked in Lancashire (manufacturing) and Cheshire (crowded)	51,240

"If the occurrence of the maximum and minimum of cases of cattle-plague, with the conditions which afford the maximum and minimum of Ozone, be only a coincidence, it is a very remarkable one.

"The Western counties of Scotland were all but free from the disease, and I am informed that it was seldom observed above an elevation of 500 feet, and no case occurred in Yorkshire above 1000 feet above the level of the sea."

NEURALGIA and INFLAMMATORY DISEASES amongst lower animals.

Mr. T. B. Morle and others have thought that neuralgia and inflammatory diseases have been more prevalent amongst animals during a continuance of strong equatorial winds bringing an excess of Ozone.

In order to ascertain whether any causal relation between Ozone and diseases, especially those of the zymotic class, does or does not exist, careful observations on the proportion of Ozone present in the air, according to the most approved method, and a simultaneous estimation of the amount of sickness and mortality, should be made. The evidence which we possess at present only enables us to state with confidence that—

CONCLUSION RESPECTING DISEASES IN MAN AND ANIMALS.

1. A deficiency of Ozone in the air in all probability predisposes to disease, particularly of the epidemic form, by virtue of the depressing and debilitating effects of such air, in consequence of its feeble powers of oxidizing animal débris; and,

2. A permanent diminution in the normal amount of active Oxygen probably favours the development of chronic diseases characterized by mal-nutrition, imperfect oxidation, and degeneration of tissues.

Experiments with fluids containing organic matter in a state of decomposition, as turnip, etc., have shown me that Ozone destroys the most elementary forms of life,

such as the germs or sporules of mould and other fungi, bacteria, vibriones, and minute monads. As the recent investigations of Chauveau and Sanderson prove that the poison of an infectious disease, as scarlet fever, measles, etc., consists of excessively minute particles of living matter which may be diffused through or wafted by the air, and that bacteria are carriers of infection, there is some reason for thinking that a *materies morbi* may be rendered inert by atmospheric Ozone.

"POTATO DISEASE."

At Culloden, near Inverness, where Ozone appears to be generally in very large quantity, a remarkable deficiency in the atmosphere of this principle has been noticed for several days prior to the appearance of the "potato disease." Although this disease has been shown to be produced by the attack of a fungus—the *Botrytis* or *Peronospora infestans*—the ultimate or predisposing cause is unknown. Whether the recurrence of this, as well as of other epidemics amongst man, animals, and plants, is in any way connected with that of periods of maximum sun-spots (about every eleven years) is a matter of uncertainty. That these cycles are accompanied by the return of electrical, magnetical, and other disturbances in the earth's atmosphere, can now scarcely be questioned. Remembering that virulent outbreaks of the potato blight are preceded by an excess of wet, thundery weather, which is generally attended by a maximum development of Ozone —a body hitherto regarded as a germ or spore destroyer— the gravest doubts will be entertained as to the value of the isolated observation at Culloden.

PROPHETIC METEOROLOGY.

It has been thought probable that the study of ozonometry might aid the meteorologist in making weather forecasts. This branch of the extensive subject which we have been considering has not been particularly investigated.

Observations of Mr. W. F. Moffat, R.N., at sea.

Mr. W. F. Moffat, R.N., has made[1] a great many observations with the object of ascertaining the amount of Ozone in different degrees of latitude and longitude at sea.

[1] *Brit. Assoc. Report*, 1867.

He found that, as the wind veered, with increased readings of the barometer, from South points of the compass through West to North, Ozone disappeared, continuing absent whilst the wind was in points between North and East, and that it reappeared as the wind veered, with decreasing readings of the barometer, to South points. The disappearance and reappearance of Ozone with those conditions were so regular that the changes appeared to be the result of an invariable atmospheric law. Mr. Moffat was led by these observations to examine Dove's law of the rotation of the wind, and the results of his study led him to believe that the polar current is the non-ozoniferous or the minimum of Ozone, and that the equatorial current is the ozoniferous or the maximum of Ozone. According to this rotation theory, the polar current in the Northern hemisphere forms the N.E. "Trade," and that in the Southern hemisphere forms the S.E. "Trade;" whilst the equatorials in the Northern and Southern hemispheres form the upper or returning "Trades." These returning "Trades" come to the earth's surface in the Northern and Southern hemispheres, about the 28° or 30° of latitude— the latitude varying with the season—N. and S. of the equator. He has pointed out that if his deductions are trustworthy, the N.E. and S.E. "Trades" ought to be the minimum, and the returning "Trades" the maximum of Ozone currents; the one in the Northern hemisphere forming the S.W., and the other in the Southern hemisphere a N.W. wind. He has endeavoured to show by tabulated results that such is the case, and has expressed a belief that, were it not for the modifying effects of the trade-winds, Ozone would be a constant quantity at sea.

Polar or non-ozoniferous and equatorial or ozoniferous currents.

Observations in North Sea and on Atlantic.

The examination of Ozone observations, which have recently been made in the North Sea, between lat. 58° and 77°, and between long. 0° and 77° W., and also of observations taken during nine passages from Liverpool to Quebec and Portland, confirms Dr. Moffat in the opinions already expressed by him regarding the phosphorescence

of the sea, and the ozonometric changes on approaching icebergs and the "icetrack." He has laid down the following rule for the guidance of mariners:—"If the sea be non-phosphorescent and Ozone be at zero, with an equatorial air current, the ship has entered either a polar sea current or the 'icetrack,' and icebergs are in close proximity." He also states that a sudden increase in the amount of Ozone accompanied by an elevation of temperature and a fall of the barometric column, are precursors of a storm.

Icetrack and icebergs.

Storms.

Results obtained from examination of records of Versailles Observatory.

Bérigny made a comparison[1] between the ozonometric curves and the meteorological tables of the Versailles Observatory, for the year 1864, which yielded him the following results:—

1. There was no maximum of Ozone which did not correspond with the presence of a gale of wind in Europe, or on the Atlantic, within sight of the coasts of France and England;

2. Storms were simultaneous with certain minima, but in these cases the gale assumed a Southerly direction before reaching the meridian of Paris, crossing Spain or the Pyrenees in its course to the Mediterranean;

3. The coloration of the tests is generally very deep when the gale traverses France or England. It varies with the force of the wind, and according to the distance from Paris at which the centre of the circular movement passes.

As the influence of storms on the chemical activity of the air extends sometimes great distances, and frequently into regions where their occurrence is unknown, it is sometimes possible to foretell an approaching atmospheric disturbance, if a sudden and inexplicable manifestation of Ozone is observed.

Hurricane of Étretat.

The following observations were made at Rouen by M. Houzeau before, during, and after the hurricane of Étretat, which occurred on September 21, 1865:[2]—

[1] *Compt. Rend.*, May 1, 1865.

[2] "Sur l'activité chimique de l'air, considérée comme un état normale de l'atmosphère, et sur la relation qui existe, entre l'accroissement de cette activité et certaines perturbations atmosphériques:" *Comptes Rendus*, February 26, 1866.

TABLE 28.

1865. Sept.	Red Litmus Test Half-iodized.	Wind.		Weather.	Remarks.
		Strength.	Direction.		
18	....	Feeble.	S.E.	Fine.	
19	....	Do.	S.E.	Do.	
20	....	Do.	S.E.	Do.	
21	.... ——	Do.	E.	Very fine.	Hurricane at Étretat (rain, thunder, etc.) at $43\frac{3}{4}$ miles N.W. of Rouen.
22	... ————————	Strong.	N.E.	Fine.	
23	...... ——————	Do.	N.E.	Do.	
24	.... ——	Do.	E.	Do.	
25	....	Feeble.	S.E.	Do.	
26	....	Do.	S.E.	Do.	
27	....	Do.	S.E.	Do.	

.... = no change.
Black lines = a change, the intensity of which is indicated by their length.

Before September 21 there is seen to have been a relative absence of Ozone in the air of Rouen. On the 21st there was a sudden manifestation of atmospheric chemical activity, when nothing in the weather indicated a change so profound and sudden in the properties of the air. On this same day a violent storm was raging at about $43\frac{3}{4}$ miles away.

Tempest of December 2d and 3d 1863.

Houzeau states that the great tempest of December 2d and 3d, 1863, which was so disastrous to the French navy, produced similar effects on his tests, which were at the time equally unaccountable.

Jansen's observations on changes in the aerial currents at sea.

Lieutenant Jansen, during his voyages to Australia and the Indian Archipelago in 1856-57, made some experiments with Ozone tests, for the purpose of ascertaining whether their indications showed the approach of a change in the aerial currents. He informs me that he found in

many cases ozonoscopes serviceable for this purpose, especially when an equatorial current is met by a polar one, the former being loaded with Ozone, whilst the latter possesses very little or none of this body.

Prophetic meteorology is still, and will long continue to be, in its infancy, so that at present but little practical outcome results from the work that has been done in this direction.

2. Why should Ozone be observed?

As Ozone has never been accurately observed, we have much to unlearn and a very great deal to learn about this body.

Some people may exclaim, in this utilitarian and money-grubbing age, "Of what use is Ozone, that you write so much about it?" Omitting all reference to its employment in the laboratory in a variety of chemical operations, we may answer this question by jotting down the following facts:—

Linen bleaching.

1. The bleaching of linen by exposure to atmospheric Ozone forms a most important industry.

Decolorization of sugar, oils, and rags.

2. It is of great service in decolorizing sugar, oils, rags, etc., and would be universally employed for the purpose if it could be manufactured, as it probably soon will be, at a cheaper rate.

Destruction of empyreumatic taste of whisky.

3. Ozone is used in America for the destruction of the empyreumatic taste of whisky. At a factory in Boston 12,000 gallons a week are thus treated.

Preparation of vinegar.

4. Vinegar is prepared from maize whisky by diluting it with seven volumes of water and subjecting the mixture to the influence of Ozone.

Dyeing.

5. The dyeing of cloth goods could not be carried on unless the air contained Ozone.

Removal of putridity from, and restoration of freshness to, meat.

6. Decomposing and putrid animal food, which is now thrown away by the butcher during the hot seasons of the year, might be restored to its wholesome freshness and purity by the employment of Ozone.

Estimation of salubrity of towns and cities.

7. The salubrity of a town or city may be pretty accurately estimated by the effects of its air on ozonoscopes, as the feebleness and sluggishness of the reaction is a very good gauge of the amount of impurities which it contains. The danger and trouble of penetrating its slums, backlets and fever-dens are thus avoided.

Deodorizing and purifying agent.

8. Ozone is a deodorizing and purifying agent of the highest order, resolving and decomposing into primitive and innocuous forms. It should be pumped into our mines and cities, and be diffused through fever wards, sick rooms, the crowded localities of the poor, or wherever the active power of the air is reduced and poisons are generated. Its employment is especially demanded in our hospitals, situated as they mostly are in densely populated districts, where the atmosphere is nearly always polluted by rebreathed air, decomposing substances and their products, and where no mere ventilation can be fully effective. If practicable, it would be highly advantageous to direct streams of sea air, or air artificially ozonised, into the fever and cholera nests of our towns. Ozone may be easily disseminated through public buildings, theatres, and other confined atmospheres, where numbers of people are accustomed to assemble, in order to maintain the purity of the air. Minute quantities of Nitrous Acid have no injurious influence on the respiratory organs. Indeed, the small proportion simultaneously evolved in the preparation of Ozone will assist the latter in depriving the air of its sewage. Air vitiated by the vaporized exhalations, and by the sensible as well as the insensible transpiration emitted by the animal frame, particularly when in a state of disease, is extremely deleterious to the healthy, and especially so to the weakly. The strong and robust may be unconscious of the reception of any harm even from frequent contact with such an unwholesome medium. That they do receive an infinitesimal, although it may be an imperceptible, amount of injury, which may or may not be repaired by the *vis medicatrix naturæ*, is certain.

Dr. Angus Smith has ascertained that the continued inhalation of air containing Carbonic Acid and the organic emanations from the body is attended by a derangement of the balance established between the respiratory and circulatory organs, in consequence of an acceleration of the action of the lungs and a retardation of the pulse, thus giving rise to a diminished vital force and an increased desire for power. Although the poison of rebreathed air is slow, it is sure, and brings about in the organism persistently exposed to its depressing effects diseased life, which is merely a perversion of healthy life, being governed by similar laws of growth and decay. Air thus deteriorated by effete organic matters—*i.e.* azotised substances in a state of putrefactive decomposition, or undergoing some peculiar fermentation-like process—if often respired by animals, lowers the tone of bodily energy and vital resistance, so as to readily permit the system to become impressed by the poison of any passing epidemic. Professor Polli has shown [1] that a dove will live longer in an atmosphere consisting *solely* of Ozone, which is highly poisonous, than in confined air which is vitiated by its own respirations.

Removal of yellow colour from old engravings.

9. Gorup-Besanez states [2] that Ozone may be employed with safety in the removal of the yellowness from old engravings and prints. It should not be allowed to act long on copper-plate engravings, or the delicate lines may suffer.

Photography.

10. Ozone is said, by Mr. J. P. Kaiser,[3] to possess the property of converting the insensitive variety of Iodide of Silver into one that is highly sensitive. This statement, if true, is of importance to the art of photography.

Ozonised oils in consumption.

11. The oils of the cod's liver, the cocoa-nut, and the sunflower, *when ozonised,* have been found by Drs. Theophilus and Symes Thompson to be very useful in reducing the

[1] *Reports from Royal Institute of Lombardy,* Series II. vol. i. fasc. xz.

[2] *Ann. der Chem. und Pharm.*, Bd. cxviii. S. 232.

[3] *Brit. Journal of Photography,* 1864, p. 392.

rapidity of the pulse, and in exerting at the same time an invigorating influence on the heart's action in consumption.

Functions in nature.

12. Last in order, but first in importance, Ozone has been considered to be probably concerned in a work most gigantic in magnitude and of vital consequence. It has been thought to be influential in the modification of climate, to exercise a beneficial action on animal and vegetable life, and to be indispensable to the relief and cure of functional disorder and disease. It has been doubted whether life could continue to exist on this planet, according to the present constitution of terrestrial laws, if the formation of Ozone should cease in nature.

Oil colours.

Dr. J. Day suggests that "the property which Ozone possesses of bleaching some colours and changing others should be made a subject of study by artists; for their work is not only exposed to the action of atmospheric Ozone, but also to the Ozone which may be generated by the Oil of Turpentine and other substances employed by them in mixing their tints."

Evidence as to relation between Ozone and disease is unsatisfactory.

Those who take the trouble to dive into, examine and review all the principal published papers, statements and observations concerning Ozone, must agree with Professor Parkes in thinking that there is no evidence of any weight whatever in support of the views regarding an etiological connection between atmospheric Ozone and certain diseases. We are not even *all* agreed as to whether it destroys the organic impurities of respiration or miasmatic exhalations. Professor Parkes, being unable to discover any ground for supposing that it does, beyond the generally accepted fact that the reaction is less in impure than in pure air, asks for experimental proof.

Dr. A. Mitchell thus writes:—"No sound conclusions can be deduced from the comparison of the fluctuations of disease with Ozone observations as at present made."

Dr. H. Day writes—"The relationship of Ozone to disease, if there be any, is confined to disease local in its character and to one part of the system,—the respiratory.

Beyond this there is no logical argument whatever, and even this must be accepted as problematical, until other potent influences are estimated as causes on the principle of exclusion."

Königstadt. Boehm states that at Königstadt, a town not particularly noted for its salubrity, he obtained indications of the presence of as much Ozone as upon the healthiest mountain; and that the coloration of the test paper is more decided in Vienna, a city noted for its lung-diseases and typhoid fevers, than in Prague which is justly ranked with the healthiest towns.

Vienna and Prague.

Observations in the Crimea. How lamentable is it that the observations made by different, and even by the same, observers should be so contradictory! In the Crimea, during the late war, it was found that at one of the observatories the quantity of Ozone was inversely proportional to the number of deaths, whilst at the other the amount of this principle and the mortality increased in the same proportion.

The mode in which observations have hitherto been conducted has been encompassed by so many fallacies, that nothing less than incomprehensible results could, in many cases, have possibly been arrived at. The popular opinion that a climate in which there is much Ozone is a healthy and exciting one, although supported by the fact that pure air exerts a strong influence, whilst an impure air has but a feeble action on Iodide of Potassium tests, wants a sufficient experimental basis.

True Antozone. As regards *true* atmospheric Antozone, nothing is yet known as to its nature. The periods of its occurrence are comparatively so few and far between, that much time must necessarily elapse before we shall be able to draw any conclusions from our investigations. Its chemical composition, the mode in which it is engendered in the air, its effects on man, animals, and on vegetation, in a state of health and disease, are quite unknown to us.

Ozone is a great bleaching agent, with whose effects all laundresses are well acquainted, and the tanning influence

of which is deplored by young ladies, especially during a sojourn at the sea-side.

Functions in the animal economy. As Ozone has been considered the great scavenger of the air when contaminated with effluvia from the dead, it has been also thought to be the physical purifier of the living animal. Schönbein believed that Oxygen undergoes chemical polarization in the body when respired, and accounts in this manner for the rapid changes which occur in the tissues. It is very probable that, when Oxygen gas is brought into contact with the blood in the lungs, a portion of it is transformed into Ozone. Some think that it is absorbed in conjunction with the Ozone contained in the inspired air, and is carried by the blood into the various tissues of the organism, where it is engaged in the oxidation of effete material. There is no proof that such is the function of Ozone in the animal economy. The subject is one of extreme interest, both to the physiological and pathological student.

Remedial virtues in disease? A systematic attempt should be made to ascertain if this body, so energetic in its affinities and so powerful in its action, possesses when artificially prepared any remedial virtues in diseases, especially those of suboxidation, such as Diabetes, the Lithic and Oxalic Acid diatheses, etc. Some interesting remarks on "The Physiological and Remedial effects of the inhalation of ozonised Oxygen as distinguished from ordinary Oxygen" have just appeared from the pen of Dr. Wilhelm Waldmann of Halle.[1]

As Ozone is so universally found to be abundant on the windward and deficient on the leeward side of cities and towns, we are almost unanimous in thinking that it is used up in the destruction of organic matters, and that those substances which hinder the formation of Ozone, if they exist in large quantities in the air, are not conducive to health, but rather to disease. It is probable that it possesses the power of destroying the infinitesimal germs

[1] *Was sind und wie wirken Sauerstoff und Ozonsauerstoff* (?) *Inhalationem?* Berlin, 1872.

or spores with which this organic matter is often associated, and which are, in all probability, the agents concerned in the spread of many diseases.

Cause of contradictory results.

The Germans tell us that the main cause of our ignorance as to the functions of Ozone in the economy of nature must be ascribed to the local influences, such as the proximity of manufactures, cesspools, marshes, and stagnant water, to which the tests are subjected; and which render the results of observations made at different parts of large towns, or at different isolated villages, variable and even contradictory.

In conclusion, it may be said that, although Ozone exists in small quantity in the atmosphere, it is doubtless a chemical agent of remarkable activity, and must have important functions to perform in nature. The variations in the amount of it contained in the air have not yet been accurately estimated. Nor has Ozone yet been observed, apart from the other air-purifiers, except by two or three savants.

Effects of Ozone to be distinguished from those of other weather factors.

The effects of these principles on animal and vegetable organisms must be carefully distinguished from those of different kinds of food, from those of light, temperature, and other weather factors. This has not been done, but conclusions have been hastily arrived at, which, although containing possibly many grains of truth, have no foundation on which to rest. Instead of endeavouring to elucidate some of the mysteries with which the subject is shrouded, writers have assumed that which has never been proved; and have contrasted the effects of air from which these agents are absent, and in which they are present, somewhat in the following quasi-sensational manner:—

Style which has been adopted by writers on Ozone.

In the confined and crowded dwellings of "the great unwashed," which form the great centres of industry made by man, where Ozone cannot penetrate, or, if it occasionally does, where it is immediately used up in the oxidation of noxious emanations, men and plants become blanched. The

skin exhibits a pallor, and all living creatures look sickly and melancholic, whilst diseases of the asthenic type predominate.

On the mountain, on the moor, at the sea-side—in one word, in the bright and beautiful country which God made—where pure invigorating air largely supplied with Ozone abounds, in which the labourer, the farmer and the fisherman are nearly always bathed, the skin is of a rosy hue, and is tanned on exposure. Men and other animals are cheerful, and living things present for the most part a healthy appearance, whilst sthenic forms of disease are encountered. The sailor, who is more exposed than the landsman to an ozoniferous atmosphere, presents this weather-beaten and tanned appearance in the highest degree.

"Nature's grand disinfectant."

Other writers have even ventured to argue that, because Ozone removes noxious odours, therefore it must arrest infection and destroy pestilential miasmata as well as the germs of epidemic disease. Hence it has been termed "nature's grand disinfectant." The presence of *true* Antozone in the air has also been declared to predispose to the spread of fevers. These statements have no logical basis on which to rest. No one has ever yet *seen* a poison-germ in the air capable of originating any morbid condition. We are not *sure* that Ozone possesses the power of oxidizing either such vitalized matter or the *materies morbi* of any known affection.

What is an unhealthy atmosphere? Conclusion respecting functions of Ozone in regard to Hygiene.

Science does not at present enable us, unfortunately, to make any positive statement as to what is or is not an unhealthy atmosphere. Believing, however, that Ozone is "vital air" *plus* force, that it decomposes some of the offensive and deleterious products of putrefaction, and that it exists naturally in the air we breathe, we may justifiably *infer* that an impairment of the active power of the air, in consequence of the consumption of its Ozone, may contribute largely to the formation of an unhealthy atmosphere.

Alas! How little does man really know of the mysterious influences by which he is surrounded, or of the effects on his mental and physical condition of those things with which he is most familiar!

HOW
IS OZONE OBSERVED IN THE ATMOSPHERE?

HOW
IS OZONE OBSERVED IN THE ATMOSPHERE?

THIS query will be most conveniently considered, like the preceding ones, by a division of the subject into two parts:—

1. How has Ozone been observed?
2. How should Ozone be observed?

1. HOW HAS OZONE BEEN OBSERVED?

Ozone acts on a small number of substances as a *deoxidizing* or *reducing* agent, but on most bodies it exerts an *oxidizing* influence. The property with which it is endowed, of forming Oxides with metals, and of converting Protoxides into Peroxides, has supplied the means of noting its presence in the atmosphere, and of making a comparative estimate as to its amount under different circumstances. The following substances have been employed as tests for atmospheric Ozone:— Oxidizing and deoxidizing agent.

1. Iodide of Potassium.
2. Red Litmus and Iodide of Potassium.
3. Pure Silver.
4. Copper and Acetic Acid.
5. Iodide of Potassium and Starch.
6. Oxide of Thallium.
7. Sulphate of Manganese.
8. Sulphide of Lead.
9. Resin of Guaiacum.
10. Indigo.
11. Fungi.

SUBSTANCES EMPLOYED IN THE DETECTION OF ATMOSPHERIC OZONE.

1. Iodide of Potassium.

1. Iodide of Potassium is, in my humble opinion, the best test for the estimation, according to the improved method, of the amount of *purifying principles* contained in the air.

2. Iodized Litmus.

2. Red Litmus paper, which has been dipped into a very dilute solution of Iodide of Potassium, appears to be the only reliable *Ozone* test, and has been employed for this purpose solely by French chemists. The Potassium set free in conjunction with the Iodine, when this salt is decomposed by Ozone, combines with the Ozone to form Potash, and the amount of this alkali is judged of by the extent to which the Red Litmus is blued.

3. Pure Silver recommended by Fremy.

3. Pure Silver. The blackening or oxidation of this metal is stated by Fremy to be the only certain test of the presence of Ozone. This test is not only inapplicable for the determination of atmospheric Ozone, on account of the labour involved in employing it and the capricious manner in which it acts, but by reason of its want of sufficient delicacy. Houzeau has shown that air impregnated with a certain amount of Ozone does not affect Silver, although it may be far richer in this active form of Oxygen than the atmosphere is ever found to be. He passed a litre (61 cubic inches) of Oxygen containing about ·010 gramme (rather more than $\frac{1}{10}$ grain) of Ozone over a plate of Silver, and found that it blackened the metal. After diluting a similar amount of Ozone with 50 litres (3051·2 cubic inches) of Oxygen, the Silver remained bright, although the mixture smelt strongly of Ozone. There is some fear, moreover, that the formation of the Peroxide of Silver effects the transformation of Ozone into common Oxygen.

Houzeau's experiments.

Employment of it by Mr. Lippincott.

Notwithstanding these assertions, Mr. Lippincott[1] has employed moistened Silver leaf, in conjunction with his Iodized Starch tests, and has observed an agreement in their indications. He affirms that "whenever the Starch tests exhibited coloration, some part of the Silver leaf was oxidized; and the greater the amount of Ozone present in the air, the quicker was the oxidation effected." The

[1] *Chemical News*, January 24, 1868.

Silver leaf was exposed freely to the atmosphere, and kept moistened by causing distilled water to pass over it. The water was conducted to it from an adjacent vessel by two or three threads of darning cotton. By observing the time which elapses before the Silver leaf is oxidized, an idea may be formed of the relative amount of Ozone present on any given day.

4. Copper and Acetic Acid.

4. Copper and Acetic Acid. A test equally impracticable, on account of the labour necessitated, is that devised by Mons. Bouchotte junior. He places a piece of Copper foil, of known weight, on a little water acidulated with Acetic Acid, and exposes the same to the air. He found that an exposure of three hours on a stormy day was sometimes sufficient to completely convert the foil into an Acetate of Copper. He then vaporizes the liquid and weighs the salt, so as to ascertain the quantity of Ozone which has been fixed.

5. Iodized Starch.

5. Iodide of Potassium and Starch. Books tell us that the sole change which these substances undergo when exposed to the action of Ozone is, (1) a decomposition of the Iodide of Potassium, which results in the setting free of Iodine and the union of the Ozone with the Potassium; and (2) a combination of the free Iodine with the Starch, forming a blue Iodide of Starch.

The three principal kinds of Ozone tests employed in this country are all composed of a mixture of these two substances, differing only in the proportion which they contain.

	Potassium Iodide.		Starch.
Schönbein's Tests . . .	1	to	10
Moffat's " . .	1	"	$2\frac{1}{2}$
Lowe's " . .	1	"	5

Mr. Lowe adds 15 grains of chalk to every ounce of Starch, to prevent sourness and to promote uniformity of effect; as he found that the intensity of action depends

Lowe's powder tests.

on the amount of water contained in the Starch. He also employs dry powder tests, made of the same chemical substances, in the proportion of 1 part of Iodide of Potassium to 5 of Wheat Starch or $2\frac{1}{2}$ of Potato Starch.

The advantages claimed by Mr. Lowe for his test powders are, not only greater sensitiveness and freedom from any proneness to fade like Schönbein's and Moffat's papers, but that by their aid we are enabled to say, *what colours the tests.* "The shades of colour and the extent of coloration produced by the various bodies which are supposed to occasionally influence the Iodized Starch test, are for the most part different from that which Ozone occasions." He, with the view of observing these differences, placed two small cups under a bell-glass, one of them containing an acid or other substance, and the other an Ozone test powder. He found that—

Hydrochloric Acid produced a *greyish pink* tint on the surface only, the powder beneath being orange;

Chloride of Lime yielded a *deep brown* colour on the surface only, below which the powder was slightly yellow;

Iodine gave a *brownish black* colouring on the surface, below which the powder was colourless;

Nitric Acid produced a *dark red-brown* colour, extending slightly into the powder which was colourless beneath;

Nitrous Acid furnished a *dark brown* surface, more than $\frac{1}{8}$ inch in depth, beneath which the powder was yellowish brown.

Ozone exerted an action somewhat analogous to that of Nitric Acid. Mr. Lowe seems, however, to have been consoled by the reflection that dilute Nitric Acid, when increased to ten times the strength which the French philosophers declare is the proportion present in the air, is far too weak to produce any colour on his "very sensitive tests."

Negretti and Zambra's tests.

Negretti and Zambra have introduced a test-paper which is considered an improvement on Dr. Moffat's.

M. Jame de Sedan's.

The tests prepared by Mons. Jame de Sedan are employed

by many French observers.

Dr. Day's.

Dr. Day of Geelong prefers tests made with 1 part of Iodide of Potassium and $7\frac{1}{2}$ of Starch.

Dr. Polli's.

Dr. Polli[1] dips strips of paper in a mixture of 10 parts Starch, 20 parts Iodide of Potassium, and 400 parts of water.

Osann's.

Osann's formula for the preparation of tests is Iodide of Potassium 3 grains, Starch 32 grains, dissolved in 4 oz. of water.

Preparation of the Iodized Starch tests

The Iodized Starch tests are all manufactured by dipping strips of paper into a mixture made by boiling Starch in distilled water, and dissolving in the solution, when cold, Iodide of Potassium. The paper is cut into slips before immersion, in order to dry rapidly and to avoid any loss of the chemicals in cutting. They are soaked in the mixture for four or five hours, and are then dried, in a horizontal position, in a cool, dark place, from which the external air is excluded. Schönbein's and Negretti's tests are moistened with water on their removal from the air, before they are compared with the chromatic scale.

Dewar's.

Some tests, recently employed by the Edinburgh observers in their experiments, which were prepared by Mr. Dewar, have been declared by them to be more sensitive and uniform in their action than Schönbein's. They are made by wetting paper with a 2 per cent solution of pure Iodide of Potassium. After their exposure they are moistened by a drop or two of a freshly-prepared solution of the best Arrowroot Starch (cold), and the tint is then observed.

6. Thallium tests.

6. Oxide of Thallium. Schönbein,[2] Huizinga,[3] and Bérigny[4] have used paper dipped in a solution of Oxide of Thallium, which becomes changed by Ozone into the brown Peroxide. My own experiments with this substance have been unsatisfactory. The Carbonic Acid of the air, unfortunately, converts it into the Carbonate of Thallium, which is uninfluenced by Ozone.

[1] *Omedei Annali*, vol. cxxxiv. p. 155.
[2] *Journal für praktische Chemie*, ci. 321. [3] *Idem*, cii. 193.
[4] *Compt. Rend.* July 1867.

How prepared by Huizinga.

Huizinga employs a 10 per cent solution of the hydrated Protoxide of this metal, obtained by decomposing a solution of the Sulphate with Baryta water. Each square centimetre of his test paper contains one milligram of this substance. He considers it to be more sensitive than the Iodized Starch test, if *freshly* prepared with a solution sufficiently concentrated.

Lamy's experiments.

M. Lamy has undertaken an investigation[1] into the relations between Ozone and the oxidation of this metal. The results arrived at by him may be thus briefly summarized:

(1.) The more or less deep coloration of the Thallium papers is a certain sign of the presence of Ozone *only* when they are able to turn the Tincture of Guaiacum blue.

(2.) Thallous Oxide papers may be used to detect with certainty and rapidity the presence of Ozone, even in the midst of a strongly nitrous atmosphere; their employment, however, should be limited to a simple confirmation of the presence of Ozone, and not extended to a determination of the amount of active Oxygen present.

Thallous Oxide, although inapplicable as a test for atmospheric Ozone, may yet be found useful in chemical operations in the laboratory.

7. Sulphate of Manganese.

7. The Sulphate of the Protoxide of Manganese, which is converted by Ozone into the insoluble hydrated Peroxide, would be the best test, were it sufficiently delicate for meteorological purposes.

8. Sulphide of Lead.

8. Sulphide of Lead. If paper dipped in a solution of Acetate of Lead be blackened, by means of Sulphuretted Hydrogen, and then exposed to ozoniferous air, bleaching will take place, the black Sulphide being converted into the white Sulphate of Lead.

9. Guaiacum Resin.

9. Resin of Guaiacum was recommended by Schönbein as a good test for Ozone. He dissolved one part of the gum in 30 parts of 90 per cent alcohol. One gramme ($15\frac{1}{2}$ grains) of ordinary alcohol having been mixed with a few drops of this solution, paper slips were immersed

[1] *Bull. Soc.*, ch. II. xi. 210; March 1869.

therein and afterwards dried. Tests made according to this formula have not been found by me sufficiently sensitive. A much stronger solution is preferable. We should add more resin, ceasing only when its colour begins to give the paper a brownish tinge.

As light and moisture have some incomprehensible effect on these tests, they are unsuitable for the estimation of atmospheric Ozone.

10. Indigo.

10. Indigo. Ozone has a peculiar bleaching effect on Indigo which, by oxidation, is converted into Isatin. It has been proposed to calculate the amount of Ozone by ascertaining the proportion of a standard solution of Indigo which it decolorizes.

11. Fungi.

11. Fungi. Two fungi, named *Boletus luridus* and *Agaricus sanguineus*, possess the remarkable property of turning rapidly blue, when the head and stem of either of them happen to be broken and exposed to the air. Schönbein,[1] who interested himself much in this matter, states that the *Boletus luridus* contains a colourless principle, easily soluble in alcohol, which bears the closest resemblance to Guaiacum in its behaviour with oxidizing and deoxidizing agents. He believed that this mushroom principle is capable of combining with Ozone and is not affected by Oxygen. The cut surface of an apple is said to become brown under the influence of Ozone.

Suggested tests.

Dr. H. Day of Stafford has suggested that a delicate test for Ozone might possibly be found by observing the difference in the colour of the electric spark passed through rarefied ozonised air, and that transmitted through ordinary air. He thought that rarefied ozonised air might have some characteristic effect on the spectrum, and advocated the employment of the spectroscope in determining this point.

Mons. P. Thenard has recommended[2] the adoption of a solution of Arsenious Acid, in conjunction with a stand-

[1] "On Ozone and Ozonic Reactions in Mushrooms." Letter to Faraday—*Phil. Mag.* (4), vol. xi. p. 137; February 1856.
[2] *Compt. Rend.*, July 22, 1872.

ard solution of Permanganate of Potash, as a test capable of distinguishing the presence of Ozone from that of Peroxide of Hydrogen and acid compounds of Nitrogen. Its use is, I fear, restricted to the laboratory, as the test appears quite unadapted for meteorological observations.

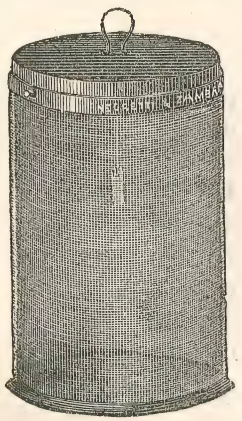
Boxes, Cages, etc. for the protection of Tests.

Ozonoscopes are generally placed in a box or cage, which permits of the ingress of air and excludes the direct rays of the sun. They are exposed for twelve or twenty-four hours, and are then compared with a numbered scale of tints called an ozonometer. Many contrivances have been devised for the protection of ozonoscopes, the principal being—1. Sir James Clarke's Cage.
2. Copper Gauze Cage.
3. Moffat's Ozone Box.
4. Lowe's Ozone Box.
5. Smyth's Ozone Box.
6. Boehm's Ozone Box.
7. Houzeau's Plate.
8. Festing's Ozone Cage.

1. Clarke's cage.

1. Sir James Clarke's cage consists of two cylinders of fine wire gauze painted over with japan, one of them being enclosed within the other. The test paper is suspended on a hook within the inner cylinder.

PLATE 8.
Clarke's Ozone Cage.



2. Copper gauze cage.

2. The Copper gauze cage is very similar in construction. Cages made of this metal should not be employed for the exposure of tests, unless the surface of the gauze is always kept coated with some material which shall protect it from the air. The minute quantity of Ammonia present in the atmosphere becomes converted into Nitrous Acid as it passes over Copper, in consequence of a catalytic action exerted by the metal.

PLATE 9. *Plan and Sections of Dr. Moffat's Box for exposing Ozone Test Papers to the Currents of Air without the Admission of Light.*

Fig. 1. Fig. 2.

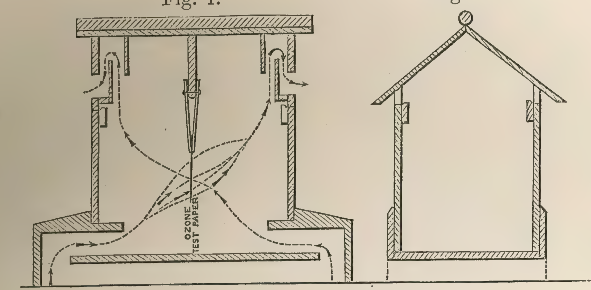
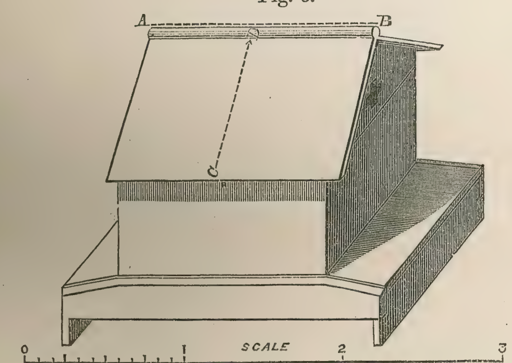


Fig. 3.



3. Moffat's Ozone box.

3. Moffat's Ozone Box. The box represented in Plate 9 was designed by Dr. Moffat of Hawarden. It is painted black in the inside. Fig. 1 represents a longitudinal section through A B, and Fig. 2 a cross section through C D.

4. Lowe's Ozone box.

4. Lowe's Ozone Box is likewise constructed to ensure perfect darkness, without interfering with the passage of a current of air. Two pieces of thin zinc, about 6

inches in width and 12 or 14 inches in length, should be bent into these forms (Fig. 1, Plate 10) and soldered together. A bottom is then affixed to the lower, and a cap to the upper which is provided with a small lid and hook for the suspension of the test paper. The box when finished will have this appearance (Fig. 3). The spirals of zinc must be connected together, so that the mouth of the one box is on the opposite side to that of the other. If an Easterly current of wind is blowing, and the upper opening is on the East side, then the air will enter the box in the upper half and move round the circular passage, until it reaches the central cavity where the test is hung; afterwards passing around the lower passage in a contrary direction, and making its exit at the West aperture. If the wind happens to be in the opposite direction, it will obtain admission at the lower half and leave the box from above. There is one great objection to this ingenious box. When the wind blows from Northerly or Southerly directions, the

PLATE 10.

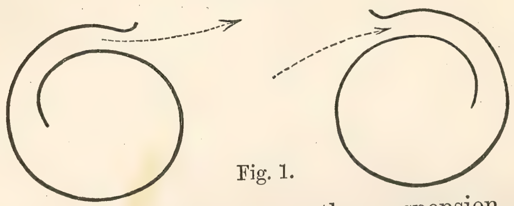


Fig. 1.

Fig. 2.

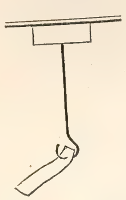


Fig. 3.

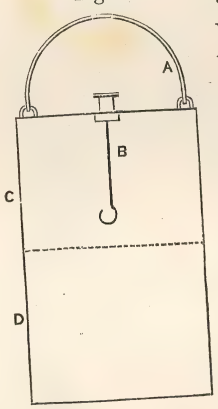


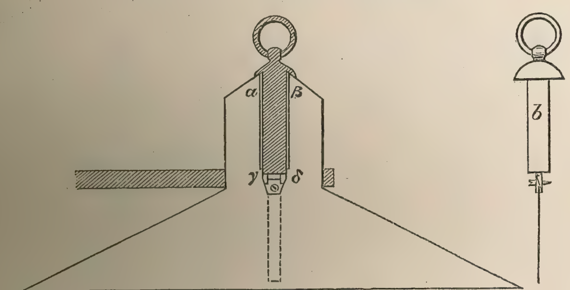
Fig. 1. Spirals of Zinc.
Fig. 2. Lid with hook and test.
Fig. 3. Box when completed.
A, Handle. C, Upper box.
B, Hook. D, Lower box.

current of air will not pass into the central chamber with the same freedom as when it is in East or West points. The coloration of the tests, *cœteris paribus*, must be less in the former than in the latter case.

5. Smyth's Ozone box will be described on page 262. 5. Smyth's Ozone box.

6. Boehm's Ozone box, for the protection of test papers from rain and sun, is simply a large funnel made of sheet-iron, and covered with a white varnish. It is attached to the extremity of a long iron bar, which allows it to be fixed at any distance from a house that may be desired. Within the narrow end of the funnel is fastened a small pipe. Into this pipe a cylinder, at the extremity of which is a clip for holding the test paper, accurately fits. The cylinder is capped to prevent the entrance of moisture. 6. Boehm's box.

PLATE 11. *Boehm's Ozone Box.*



α, β, γ and δ indicate the whole length of the pipe inserted firmly within the upper part of the funnel.

b, The cylinder, furnished with a test, which is introduced into the box.

The Ozone box employed by the Königsberg observers is made of tin. It possesses three walls, the lateral ones being perforated with holes, and a slanting roof. Box used by the Königsberg observers.

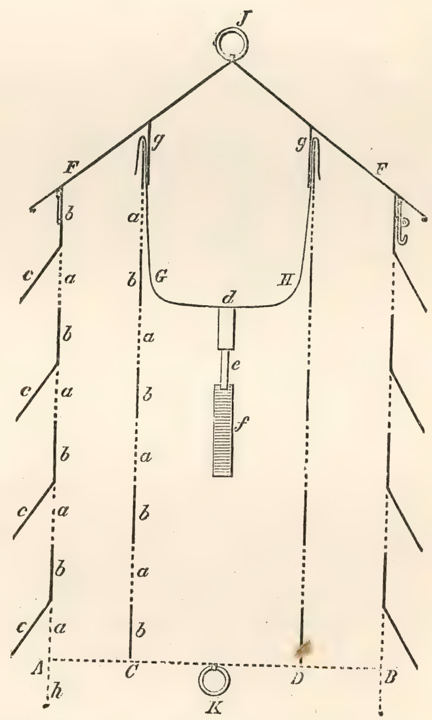
Ozonoscopes are suspended in a simple square wooden box with an opening at the bottom, by Dr. Rogers and others in America, which shields them from rain, snow, and strong light. Box employed in America.

7. Houzeau's Plate.—Houzeau exposes his tests be- 7. Houzeau's plate

neath a deep plate pierced in its centre with a hole, through which passes a cord that is secured by a knot to a disc of cork on which the plate rests. The other extremity of the cord serves to fix the plate in a place which may be considered most convenient. The test paper is affixed to the cork by means of a pin.

8. Festing's Ozone cage. 8. Festing's Ozone Cage.—Mr. Morton Festing strongly recommends[1] a cage of the following construction, which affords him every satisfaction, and is not expensive.

PLATE 12.



"A B C D is a circular plate of finely perforated metal, to which two concentric cylinders are attached at A B and C D, with a space of two inches between them.

[1] *Proc. of Meteorological Society*, vol. iv. No. 38, 1868.

"Each cylinder is also finely perforated round its entire circumference in alternate spaces $1\frac{1}{2}$ inch deep, as at *a*, *b* representing the spaces not perforated; and A B and C D are so adjusted with reference to each other, that the spaces at *a* of the former shall oppose those at *b* of the latter, and *vice versâ*.

"A B has a rim at *h*, also perforated, upon which the instrument rests when not suspended. *c*, *c* are louvres protecting the spaces at *a*, *a* in the outer cylinder.

"F F is a conical lid attached by a hinge to the outer cylinder; at *g* is a deep rim which fits into the inner cylinder in order to steady it.

"G H is the test-paper suspender, a strip of metal bent into the required form. *d* is a small tube into which a partially split piece of cane, *e*, is admitted; *f*, the test-paper suspended therefrom.

"G H is capable of being detached, and hangs from the top of the inner cylinder, where it is secured by means of *g*.

"J and K are two rings used in suspending the cage. From the construction of the above instrument it will be seen that the papers are entirely protected from sun and rain, and at the same time freely exposed to the air, as a careful examination of the above diagram will show, from which also the mode of using it may be easily seen."

Tests are sometimes hung under the roof of the thermometer stand, and, at others, in louvre boxes which are attached to walls. The majority of these cages and boxes only shield the tests from direct sunlight, hail, rain, and snow. They do not exclude the diffused daylight which influences ozonoscopes. None of them prevent the entrance of moisture in foggy weather.

M. André Poey introduced, at the Séance of the French Academy of Sciences, on December 18, 1865, an instrument, which he called an Ozonograph and Actinograph, intended to register half-hourly the atmospheric Ozone and the chemical action of light. It consists of drums to carry the papers, and clockwork to move them, with arrangements to admit air and light. Ozonograph and Actinograph.

A contrivance, named a "Chronozonometer," was described[1] by MM. Bérigny and Salleron in a paper on "A New Ozonometric Method" which appeared in 1867. These gentlemen, having reasons for believing that complicated changes take place in the Iodide of Starch as a "Chronozonometer."

[1] *L'Institut*, December 11, 1867.

result of an exposure of twelve hours to the air, preferred to estimate the amount of atmospheric Ozone by measuring *the length of time required, in order that a test may assume a colour fixed and determined*—viz., the fourth tone of the first violet in M. Chevreul's chromatic circles. If, on a certain day, a test takes one hour to reach this tint, and, on the next day, two hours are necessary, only half as much Ozone is evidently present on the second day as on the first. In the same way, an exposure of a half-hour will correspond to a double amount. To determine the duration of the period necessary for the test to acquire the standard tint, they employed a drum, moved by clockwork, which unfolds to the air from protection to exposure, at a definite velocity, a band of test-paper 12 centimetres long. Suppose, for example, that this machine unrolls the paper with the velocity of a centimetre per hour; after twelve hours there will be a length of paper exposed equivalent to 12 centimetres. The first centimetre of the paper will have been exposed for twelve hours, the second for eleven hours, and so on to the last which will only have been influenced by the air for one hour. The band of paper, after its removal from the instrument, having been plunged into distilled water, displays colours varying between white and dark violet. It is now only necessary to compare the various tints with the standard colour, and to note the position on the band where they are identical. The number of hours are then known which were required by the colourless test to reach this particular tint.

Mr. Cann-Lippincott's self-recording instrument

A self-recording instrument for the hourly registration of Ozone has been devised and employed by Mr. Cann-Lippincott. The observations referred to on pages 63 and 64 were made by means of this apparatus. He gives the following description of it:—[1]

"Two cylinders (one large and the other small) are

[1] *Proc. of Meteorological Society*, vol. iv. 1869, p. 326.

inclosed in boxes, the openings of which are guarded by india-rubber lips. The boxes are $2\frac{1}{4}$ inches apart. The large cylinder is moved round $2\frac{1}{4}$ inches each hour by means of a driving-shaft attached to the clock.

"A strip of Schönbein's test-paper about $\frac{5}{8}$ of an inch wide and 5 feet long is rolled round the small cylinder, the free end of it being fastened to the large cylinder; $2\frac{1}{4}$ inches of paper are thus exposed to the influence of the atmosphere.

"The clock, which goes eight days, indicates the minutes only, and *shifts the paper*, by causing the large cylinder to rotate $2\frac{1}{4}$ inches of its circumference, *exactly at the hour*, thus removing the portion of paper ($2\frac{1}{4}$ inches long) exposed during the past hour, and exposing a fresh portion, to be in its turn removed at the end of another hour and succeeded by a new piece, and so on.

"At the end of the twenty-four hours the whole strip of test-paper is unrolled by the observer from the large cylinder, dipped into distilled water, and read by the scale; a fresh strip is then rolled round the small cylinder, and its free end is attached to the large cylinder, as before."

Lankester' self-recording apparatus.

Dr. Lankester has also contrived a self-registering mechanical Ozone observer, containing clockwork, whereby an inch of prepared paper is made to pass each hour beneath an opening in the cover.

Dr. E. Boeckel's suggested arrangement.

A complicated arrangement has been suggested by Dr. E. Boeckel. He proposed in 1856 that air should be examined in a chamber, the temperature of which never varies to any extent; that, before its examination, it should be passed through warmed or cooled tubes, in order that it may be brought to the same temperature; that the air should then be saturated with humidity, by transmitting it through U tubes containing water; that air, thus brought constantly to the same condition of temperature and humidity, should be passed over the test by an instrument of the construction of a winnowing

machine, moved by clockwork, to ensure always the contact with the test of the same amount of air.

Chaotic State of Ozonometry.

The truth of the statement, that the estimation of Ozone, as it has hitherto been conducted, is eminently unsatisfactory, will not be disputed even by the most inexperienced of observers. A Fellow of the Meteorological Society has recently only echoed the sentiments of hundreds, when he publicly declared the investigation of Ozone to be "a delusion and a snare." The test papers seem to play such mad pranks: now they colour; then they bleach; sometimes they tint in a uniform manner; at other times they become marked with lines and spots; whilst they very frequently fade. Hence the records of observations appear most contradictory, forming a mass of almost inextricable confusion. In support of this assertion, the opinions of a few, who have made Ozone a subject of study, may be quoted:—

Opinions of distinguished observers.

"At the present time, the modes of determining Ozone and the tests for Ozone in the external air are very unsatisfactory."—Dr. Richardson.

"The greater part of the countless observations on the amount of Ozone in the air are worthless."—Prof. Heaton.

"The determinations which have hitherto been made are very vague and unsatisfactory."—Dr. Wetherill.

"Tests prepared from the same recipe, by different persons, give varied results."—Boehm.

"If we expose the tests of Schönbein and Moffat together we do not get the same result, and even tests made by the same persons at two different times will not read alike."—Mr. Lowe of Nottingham.

"All the methods employed are more or less defective."—Dr. Scoresby-Jackson.

"Until more certain means are discovered for estimating Ozone, present observations must be received with great caution."—Davies.

"The estimation of Ozone is in a very unsatisfactory state. The great imperfection in the tests makes it desirable to avoid all conclusions at present."—Prof. Parkes.

"No clear and consistent results have yet been obtained. Variations of light, wind, time, and paper, may cause changes attributed only to Ozone, and there are no reliable means of checking them."—Admiral Fitzroy.

"No trustworthy observations on Ozone are made in the United States of America."—Dr. Henry of the Smithsonian Institution.

"No method has yet been devised by which it can be ascertained that Ozone, *and Ozone alone*, is the colouring agent."—Report on Ozone Observations by a Committee appointed by the Council of the Scottish Meteorological Society on January 14th, 1869.

These views refer to the Iodized Starch test, and its mode of employment by suspension in a cage or box. We shall hereafter see that these tests not only indicate the presence of Ozone, but of other agents which are sometimes found in the air, such as the Peroxide of Hydrogen, Nitrous Acid, etc. Unhappily, they do not truthfully indicate the sum total of these purifying principles.

Improved method of ozonometry.

It has been my endeavour, for some years, to ascertain the causes of the eccentricities on the part of the tests, and to establish Ozone investigations on a thoroughly sound and intelligible basis. My experiments led me to conclusions, at which, most curiously, Prof. Crum Brown had independently arrived.

Encouraged by this confirmatory evidence, I pushed onwards; and, at length, submitted a scheme for the correct estimation of Ozone to the British Medical Association at their annual meeting in 1871.

Errors inherent in old method.

Before describing the new scheme, it is desirable that the sources of error involved in the old method should be fully pointed out.

ERRORS ASSOCIATED WITH THE OLD OZONOMETRIC METHOD.

1. Impurity of Chemicals, } Employed in the Manu-
2. Impurity of Paper, } facture of the Tests.
3. Formation of the Iodate of Potash.
4. Non-union with the Starch of the whole of the liberated Iodine.
5. Changes in the force of the wind.
6. Bleaching and fading of coloured tests from—
   - A. Formation of the Iodate of Potash.
   - B. Excess of moisture in the air.
   - C. A high temperature of the air.
   - D. A great velocity " " "
   - E. A long exposure to " "
   - F. Sulphurous Acid in " "
   - G. *True* Antozone " " "
7. Light.
8. Ozonometers faulty in construction.
9. Differences of aspect and elevation.

1. *Impurity of Chemicals employed in the Preparation of Tests.*

(*a*) Potassium Iodide

The *Potassium Iodide* of commerce is a salt which is liable to, at least, six important adulterations or impurities.

Reagents for the detection of impurities.

Free Alkali (probably Potash) detected by Turmeric or Red Litmus.

Carbonate of Potash, detected by Lime Water and Chloride of Barium with Nitric Acid.

Sulphates of { Potash, Soda, Lime, } detected by the Chloride of Barium and Nitric Acid test.

Chlorides of { Potassium, Sodium, } detected by the Nitrate of Silver and Ammonia test.

Iodate of Potash, detected by Tartaric Acid.

If a yellow tint is occasioned, by dropping into a solution of Potassium Iodide sufficient Acetic Acid to render it very faintly acid; and if, when a little Starch is added, a violet colour more or less deep is developed, free Iodine is present in the salt. Neither of these colours is produced, under the same circumstances, when the Potassium Iodide is devoid of this metalloid in a free state.

M. Payen's analyses of continental specimens.

M. Payen,[1] who has made careful analyses of a great number of specimens of Potassium Iodide, as supplied to the various industries, to chemists and to medical men, informs us that every specimen which he has been able to procure has exhibited a marked alkalinity, due to variable proportions of Carbonate of Potash, and that nearly all contained also free Iodine. He has also shown that Potassium Iodide containing these impurities, is readily decomposed by the Carbonic Acid of the air and by light, whilst pure Potassium Iodide is unaffected by this acid, and by a brief exposure to light.

Pure Potassium Iodide is neutral, that is to say it neither colours blue nor red Litmus papers. The alkalinity of the salt lessens, to a great extent, the sensibility of the Iodized Starch tests, sometimes almost entirely destroying it. If, then, ozonoscopes be made with Potassium Iodide of different degrees of alkalinity, and be exposed together to an ozonised atmosphere for the same length of time, they exhibit differences in tint. Although the Potassium Iodide sold in this country would appear to be of greater purity than that manufactured on the Continent, if the following samples[2] obtained from different chemists in London are fair representatives, any one possessing a knowledge of chemistry will thoroughly appreciate the importance of the occasional presence in this salt of the impurities below indicated.

London specimens.

[1] "Iodure de Potassium et Réactions comparées des Iodures Bromures et Chlorures Alcalins :" *Annal de Chimie et de Physique*, Oct. 1865.

[2] *Practitioner*, January 1872.

TABLE 29.

ANALYSES of SPECIMENS of POTASSIUM IODIDE procured in London.

No.	Moisture.	Potass. Carb.	Iodine.	Chlorine.	Iodate.
I. . .	1·16	None.	74·15	0·40	None.
II. . .	1·69	None.	73·75	0·35	None.
III. . .	1·90	None.	74·10	0·25	None.
IV. . .	·66	None.	76·88	0·25	Minute Trace.
V. . .	2·20	1·24	72·76	0·12	None.
VI. . .	0·83	None.	74·15	0·80	Trace.

(*b*) Starches

The *Starch* of commerce is notoriously impure, Sulphuric Acid, Lime, and Chlorine—substances which act on the Iodide of Potassium without the aid of Ozone—being employed in its manufacture. Fine carefully-made Starches from the following plants have been used by Mr. Lowe in ozonometric experiments :—wheat, barley, oats, rye, rice, sago, tapioca, potato, crocus, arrowroot, Indian corn, snowdrop, tulip, narcissus, arum, etc. All these starches appear to act differently from one another, when mixed with a certain amount of Potassium Iodide and exposed to the air. Mr. Lowe is now, I believe, engaged in ascertaining the kind of Starch which forms, with this salt, the most sensitive test, as he has discovered that a special formula is requisite for each.

Dr. Allnatt has also found out the necessity of avoiding the use of the Starch of the shops in the preparation of his tests, not only on account of its being an inherent source of impurity, but because of its variation in strength.

2. *Impurity of the Paper employed in the manufacture of Tests.*

The various kinds of paper in general use, and nearly all bibulous paper, are chemically impure. Sulphites and Chlorides, which serve as useful bleaching

agents, can be detected with ease and certainty in papers. Lime, Silica, and Oxide of Iron are generally found even in good filtering papers. The glazes with which papers are covered are fertile sources of impurities. Starch is found in most papers. The best English and French filtering papers contain this substance, as well as spots of some reducing material. Some photographic papers have been employed which are of very questionable purity. Tests made with impure paper are more sensitive than those manufactured with the pure article, for the decomposition of the Potassium Iodide is aided by the reducing agents. Tests of great sensibility have been found to colour after a lapse of time, although kept in places inaccessible to air and light. Some observers accordingly object to the use of sensitive tests, because in truth they do not improve with age like their port! Impurity of the chemicals or of the paper is to be strongly suspected when such an accident occurs. The extremely delicate and pure 10 or 15 per cent Potassium Iodide tests which I employ never colour, if, having been carefully prepared, they are preserved in a cool dark place enclosed in a red or black stoppered bottle. Common writing paper, which is very impure, is said to be employed in the preparation of Dr. Moffat's ozonoscopes. These tests are, moreover, recommended by the British Meteorological Society! All the so-called ozonoscopes in the trade, which I have examined, are made of paper containing some reducing material.

Glazed papers exceedingly objectionable.

Non-coloration of perfectly pure tests, if carefully prepared and properly preserved.

3. *Formation of the Iodate of Potash.*

The reaction which occurs when a simple Potassium Iodide test is exposed to the air consists of a decomposition of this salt, Iodine being set free and Potash formed by the oxidation of the Potassium. Baumert and other chemists assure us that, when free Potash is associated with free Iodine and both are exposed to the air, there is a tendency to the development of an Iodide and an Iodate of Potassium. Prof. Crum Brown thus writes :—

Chemical changes in the Iodide of Potassium when exposed to the air.

"When Ozone acts on moist Iodide of Potassium, it at first produces Caustic Potash and free Iodine; part of the Iodine is removed by evaporation, and part acts on the Caustic Potash forming Iodide of Potassium and Iodate of Potash, $\frac{5}{6}$ of the Iodine being taken up in producing the Iodide and $\frac{1}{6}$ in the Iodate. These alternate actions may go on, if sufficient Ozone be present, until only Iodate of Potash remains." A portion of the Iodine set free by the Ozone has been said [1] to be converted by additional Ozone into Iodozone, a substance which is extremely volatile at ordinary temperatures, and is changed, in the presence of a certain amount of moisture, into free Iodine and Iodic Acid.

Iodozone.

The coloration of an Iodized Starch test by Ozone is generally considered to be due to, first, a decomposition of the Potassium Iodide; and, secondly, a combination between the liberated Iodine and the Starch producing the blue Iodide of Starch. The chemical changes which take place are not, in fact, so simple. They have been regarded as extremely obscure, and been described in a different manner by various chemists.

Reactions which occur when an Iodized Starch test is subjected to influence of air.

Dr. Debus, in a lecture delivered before the Chemical Society on June 1st, 1871, thus explains the reaction.[2] In the first place, the Potassic Iodide being in excess, Ozone forms, in presence of water, Potash and free Iodine. The excess of Potassic Iodide will prevent the Potash from attacking the Iodine, but will allow the latter to act upon the Starch. But as, by degrees, the Potassic Iodide is decomposed and diminished in quantity, the Potash commences to act on the Iodine and to form Potassic Iodate and Iodide. The latter is acted upon by the Ozone, until a certain amount of Potash has accumulated and can, with free Iodine, form the Iodate and Iodide. This process goes on until all the Iodide is converted into Iodate, and the mixture has lost its blue colour.

[1] *Beitrage zur Ozonometrie*, von Dr. Maach; *Archiv. für Wiss. Heilk.* Band ii. p. 29.

[2] Abstract in *Chemical News*, June 9th, 1871.

The amount of free Iodine in the simple Iodide of Potassium test, and that of the blue Iodide of Starch in the Iodized Starch test, cannot therefore be accepted as truthful indicators of the amount of Ozone which has acted.

Observers sometimes find that their test-papers do not colour, and, at others, that they fade and even bleach. These phenomena are due to several causes, which will be presently adverted to. One of them is to be found in the conversion of the Iodine and Caustic Potash, which have been set free by the Ozone, into a colourless mixture of the Iodide of Potassium and the Iodate of Potash. Here, then, we have a gigantic source of error in the estimation of Ozone, which happily, however, can be corrected. If the quantity of the Iodate of Potash produced was not variable, much of the difficulty would be removed. Sometimes this salt cannot be detected in a test which has been exposed to the air; at others, a small proportion of it is found; whilst, occasionally, an abundance is apparently formed.

Produces bleaching of coloured tests.

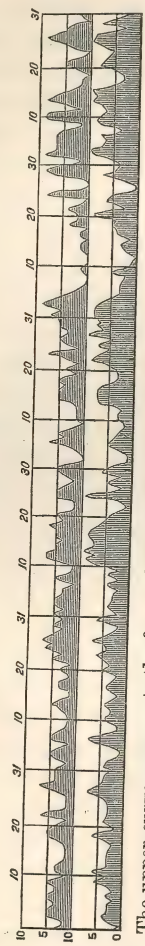
4. *Non-Union with the Starch of the whole of the Liberated Iodine.*

The failure on the part of some of the Iodine to combine with the Starch and form the blue Iodide does not uncommonly occur. It is a serious source of error, for the amount of the blue Iodide in such a case does not represent the quantity of Ozone which has influenced the test. That Iodine does often remain in an uncombined form in the test may be proved by making the following experiment:—Divide a Schönbein's test which has undergone an exposure to the air into two parts, and dip one part in a cold solution of starch, and the other portion in distilled water. It will *sometimes* be found that the former will assume a deeper tint than the latter, in consequence of the presence of free Iodine, which had not combined with the Starch, when disengaged from the Potassium. This fact was especially noticed by Mr. Buchan

Experiment in proof.

and his coadjutors, whilst conducting their experiments with aspirators at Edinburgh.

PLATE 13.



The upper curve represents the force of the wind, and the lower curve indicates the depth of test coloration. The Ordinate for the Wind is 12 hours in advance of that for the Ozone.

The uncombined Iodine does not contribute to the coloration of the test when its tint is estimated; for the water, into which the majority of Iodized Starch tests are dipped before the comparison with the chromatic scale is made, immediately dissolves any free Iodine that may be present.

5. *Changes in the Force of the Wind.*

Every one who has employed Ozone tests must have observed that the intensity of the colour is affected by the force of the wind. During a calm day there is frequently but little tinting; whilst, during a high wind, the coloration is often very deep, so that the instrument for measuring the amount of Ozone becomes rather an anemometer than an ozonometer.

Ozone tests regarded by some as anemometers rather than ozonometers.

The accompanying diagram, which exhibits the parallelism between the wind and Ozone curves at Banbridge, may be taken as a sample of the experience of all observers.

It must not be thought that this increase of colour during stormy weather necessarily indicates the presence of a larger amount of Ozone in the air. If the same quantity be present on any two consecutive days *a* and *b*, and if the force of the wind during *a* is three times greater than that during *b*, a test exposed on *a* will exhibit a deeper tint than one treated in the same manner on *b*, simply because a *larger amount*

of air charged with Ozone will have passed over the test paper.

Experiment.

The following very simple experiment illustrates the truth of this explanation:—Affix one test-paper to the front and another to the back of your hat, when starting for a walk. If there is any Ozone in the air, you will find, on your return, that the test in front is much darker than the one placed behind. The former, having been subjected to a more rapid change of air, indicates, by its deeper coloration, the fact of its having been influenced by a larger amount of active Oxygen.

Dr. Mitchell's explanation.

Dr. Mitchell well explains the fallacy arising from the varying velocity of the wind, thus:[1]—"Let me suppose that a bit of Schönbein's test paper is exposed during a perfect calm. It will then be acted on only by the Ozone in the air immediately surrounding it. This may be far too small in quantity to set free an amount of Iodine sufficient to give an appreciable indication with the Starch; or it may happen to be in such abundance as just to give a trace of discoloration. Let me now suppose another similar bit of paper exposed to the same atmosphere—that is, to an atmosphere containing exactly the same percentage of Ozone—but which, instead of being calm, is in a state of rapid motion; in other words, a strong wind is blowing. A continuous stream of air, carrying with it the reagent, now flows over the paper, fresh Ozone arriving at each instant to add to and increase the indication by setting more and more of the Iodine free. The paper is then examined, and No. 9 or No. 10 entered on the table as the representative of the amount of Ozone in the atmosphere. Now, in both of these cases the percentage of Ozone is exactly the same; yet in one case the test shows 0 or a trace, and in the other 10 or a maximum. Schönbein's test paper cannot therefore be taken as a faithful measurer of the varying proportions of this

[1] *Quarterly Report of the Meteorological Society of Scotland*, March 1860.

substance in the air; nor even as one which approximatively speaks the truth, since it is capable of so large an error."

The fallacious indications of ozonoscopes, when exposed in cages and boxes, in consequence of the ever-varying force of the wind, or, in other words, of the continual changes in the quantity of air passing over them, have stimulated the inventive faculties of meteorologists. The late secretary of the Scottish Meteorological Society, Mr. Burgess, suggested the construction of a table, by which the percentage of Ozone existing in the atmosphere might be found from the two data—the indication on the paper and the wind force.

Wind error Table of Mr. Burgess.

TABLE 30.

Mr. Burgess's Table for Correction of Wind Error.

4	3	2·5	2	1·5	1	0
I. . . .	2	3	4	5	6	7
II. . . .	3	4	5	6	7	8
III. . . .	4	5	6	7	8	9
IV. . . .	5	6	7	8	9	10
V. . . .	6	7	8	9	10	11
VI. . . .	7	8	9	10	11	12
VII. . . .	8	9	10	11	12	13
VIII. . . .	9	10	11	12	13	14
IX. . . .	10	11	12	13	14	15
X. . . .	11	12	13	14	15	16

"The numbers in the upper line are the relative velocities of the wind, and the first vertical column contains the numbers of the Ozone scale; the others are the numbers to be registered as the percentage of Ozone in the atmosphere. Thus if, after an exposure for a definite time, the Ozone paper shows No. 7 of its scale, and if the mean velocity of the wind for the same time is

2·5 of the wind scale, the entry of Ozone to be made by the observer is No. 9; whereas, had the wind been calm, it would have been 13. This also implies that 1 on the Ozone paper in calm air shows the same percentage of Ozone as 6 does when the wind blows strongly." A table of this kind would be extremely convenient if a correct one could be constructed. The above is framed on a false assumption—namely, that the augmentation of Ozone indication by each grade of wind force is about the same. My experiments show that the ratio of increase is more complex.

Similar objections may be urged against the mode adopted by some German experimenters, who, recognizing the important part which the force of the wind plays in the tinting of ozonoscopes, have been in the habit of dividing the number of degrees of colour by its velocity. The following tables, extracted from some German publications, exhibit the manner in which they thus correct their observations.

Plan adopted by the Germans for the correction of the wind error.

TABLE 31.

Coloration with reference to the Months.

	Total of		$\frac{\Sigma.F.^1}{\Sigma.W.^2}$
	Wind.	Coloration.	
January	25	192·5	7·70
February	51	451	8·84
March	27	228	8·44
April	37	326	8·81
May	28	195·5	6·98
June	44	321·5	7·31
July	39	250	6·41
August	45	341·5	7·59
September	19	151	7·95
October	16	142	8·87
November	24	161	6·71
December	39	339	8·69

TABLE 32.

COLORATION with reference to the DIRECTIONS of the WIND.

	Σ.W.[2]	Σ.F.[1]	Σ.F.[1] / Σ.W.[2]
S.W.	286	755·5	2·64
W.	597	2087·8	3·58
N.W.	185	300·3	1·62
N.	183	222·5	1·22
N.E.	98	62·0	0·63
E.	145	64·8	0·45
S.E.	41	23·5	0·57
S.	176	128·1	0·73
Still	1211	326·5	0·27

[1] Σ.F. = Total of coloration. [2] Σ.W. = Total of wind force.

6. *The Bleaching and Fading of Coloured Tests.*

Although observers, ever since the time when Schönbein initiated the great Ozone crusade, have remarked the tendency which their tests display to fade or become occasionally colourless, after having been deeply tinted, the various causes which produce the discharge of colour have never been thoroughly determined or explained. The depth of the tint assumed by an ozonoscope during its exposure should, of course, be the measure of the amount of Ozone which has acted on it. Any removal of colour from tests must obviously, then, be a great source of fallacy in ozonometry. Observers are often perplexed at finding that a test paper of a deep reddish-brown or violet colour is rendered in a short time perfectly colourless. A meteorologist thus writes:—"I have looked at the tests at 9 P.M. and found them as black as No. 8 of the scale, and even more. The next morning they were as white as when first hung up. More than this, I have hung up a paper at 9 A.M., and seen it at noon dark-

Perplexity of observers.

ened. Then came rain and wind, and at 3 P.M. the paper was white again. The stand I hung these papers in was of Stevenson's pattern, into which I thought no rain could get, but I cannot help thinking that rain has something to do with it."

We shall presently see that air containing an excess of humidity is a most powerful agent in the decolorization of ozonoscopes.

A Fellow of the Meteorological Society writes in the following manner concerning observations made by him at Wolverhampton in July 1870.[1] "With reference to the following table, it will be seen that the mean of the readings of Negretti and Zambra's tests for the 24 hours is less than that of the day hours. This result I was not prepared for, and am totally at a loss to explain. On several occasions, the paper, which was coloured to the extent of No. 5 of the scale (as on July 10th), lost its colour during the night, and was as colourless at the end of the 24 hours as when first placed on the hook."

Results of observations considered inexplicable.

[1] *Meteorological Magazine*, September 1870.

TABLE 33.

1870.	Day. 9 A.M.—9 P.M.	Night. 9 P.M.—9 A.M.	24 Hours.	Wind.
July 1 . .	9	9	10	N.W.
„ 2 . .	7	7	8	„
„ 3 . .	6	0	0	„
„ 4 . .	3	6	7	S.W.
„ 5 . .	0	6	8	„
„ 6 . .	4	2	3	W.
„ 7 . .	4	1	1	S.W.
„ 8 . .	3	0	0	„
„ 9 . .	3	5	6	Calm.
„ 10 . .	5	0	0	W.
„ 11 . .	6	5	6	N.E.
„ 12 . .	6	0	1	N.W.
„ 13 . .	4	5	7	„
„ 14 . .	6	0	3	S.W.
„ 15 . .	4	4	4	„
„ 16 . .	6	7	10	W.
„ 17 . .	5	1	2	„
„ 18 . .	0	0	0	S.
„ 19 . .	3	1	3	S.W.
„ 20 . .	4	0	0	W.
„ 21 . .	3	2	2	N.W.
„ 22 . .	4	0	0	E.
„ 23 . .	2	0	0	
„ 24 . .	2	0	0	

The bleaching or fading of ozonoscopes, which have undergone coloration from an exposure to the air, is produced by

A. *The Formation of the Iodate of Potash,* which has already been described (page 187).

B. *An Excess of Moisture in the Air.*

Whilst a normal amount of moisture in the air promotes chemical action and, consequently, the coloration of the test, an excess of humidity very often removes all colour.

Observers are very often astonished at finding, during wet or foggy weather, that their coloured ozonoscopes have become completely bleached. This accident is due to the vaporization of the blue Iodide of Starch with the moisture that has come into contact with it. If any free Iodine, which has not united with the Starch, exist in the coloured test, it is either volatilized or dissolved. The difficulty of protecting the tests in rainy weather is great, especially when the wind is high. During the prevalence of a dense fog, it becomes quite impossible to prevent the contact of moisture, when ozonoscopes are suspended in the boxes, cages, and other contrivances that have, up to the present time, been in vogue. The disappearance of colour is also partly due to the fact that the Iodide of Starch is slightly soluble in water. Its solubility is much greater when the Iodide of Potassium, of which the test is made, is alkaline than when it is neutral. The removal of colour from an Iodide of Potassium test, which has been tinted by Ozone, occurs most frequently in consequence of the volatilization of the free Iodine, which is exceedingly liable to happen when this metalloid is in a moist condition.

Vaporization of Iodide of Starch.

Impossibility of protecting tests suspended in boxes, cages, etc., from fogs.

C. *A High Temperature of the Air.*

It has been already shown that all of the Iodine, set free during the exposure of an Iodized Starch test to the air, does not sometimes combine with the Starch to form the Iodide. This free Iodine is volatilized when the temperature is high, especially if the air be moist. Mr. Smyth tells us that a quantity of liberated Iodine, on the amount of which in the ozonoscope our calculations are based, is generally found inside the double wire gauze cage.

Volatilization of free Iodine.

The vaporization of the Iodide of Starch is promoted, when the air is very damp, by a high temperature. M. Houzeau, who has also noticed the disturbing effects of variations in temperature on ozonoscopes, states that he has "observed a coloured test to become perfectly colourless in fifteen minutes, when exposed to air saturated with

moisture, the temperature being 82·4° Fahr., which is somewhat inferior to that of some summer winds."

D. *A Great Velocity of the Air.*

When coloured Iodized Starch tests fade or become blanched during a period characterized by the approach of a warm and very moist current of air, it will be found that the removal of colour is greater and takes place with more rapidity, when the velocity of the wind is great than when it is feeble. The vaporization of the moist Iodide of Starch is promoted by the transmission over it of air of great velocity.

Volatilization promoted by passage of a rapid current.

It is well known that free Iodine is particularly volatile at high temperatures. When a rapid current of air is passed, under certain atmospheric conditions, over an Iodide of Potassium test, this loss of the metalloid by volatilization is much increased. There may be a considerable amount of Ozone in the air, yet a test will sometimes fail to show the presence of a trace, when it is exposed to a humid and warm current of great velocity. Even when a slow current of air is passed over a coloured Iodide of Potassium test, during a period when no Ozone is present, a diminution in the depth of the tint will be observed from volatilization, if the temperature, or temperature and humidity, of the air be great. It is evident, then, that tests made of Potassium Iodide should only be exposed to air of very slight velocity, otherwise a serious error must often occur.

Explanation of Mr. Smyth's error.

It is probable that one of the causes of the extraordinary results at which Mr. Smyth jun. has arrived, as to the absence of all fluctuation in the amount of atmospheric Ozone, is to be found in the great velocity of the air (from 4 to 9 miles per hour), which he passed daily, by means of aspirators, over his Iodide of Potassium tests.

E. *A Long Exposure to the Air.*

Long exposures introduce several fallacies into ozonometry. The effect produced on an ozonoscope at the commencement of its exposure is frequently modified or destroyed by subsequent changes in the temperature and

hygrometric condition of the air. Many observers must have remarked that ozonoscopes, which have become strongly coloured by an exposure to the air of twelve or twenty-four hours, gradually lose their tints if allowed to remain in the air for several days or weeks. A few hours are sometimes sufficient for the removal of much of the colour of a test tinted to its maximum degree. Houzeau pointed out many years ago that an Iodized Starch test, which has undergone a deep discoloration in contact with Chlorine, compounds of Nitrogen, or the vapour of the essence of Turpentine, loses its colour in a similar manner, when subjected to the prolonged action of these bodies. An Iodized Starch, or an Iodide of Potassium test, exposed to the vapour of a strongly ozonised Ether, will soon assume the most intense coloration. If either test be subjected to its influence for a much longer period, the colour will gradually diminish. Scoutetten thinks that the Iodide of Starch becomes decomposed if allowed to remain in contact for some time with the air. It seems very probable that this compound (?) undergoes during a lengthy exposure some chemical change, possibly similar to that experienced by vegetable colours, of which Ozone is a powerful bleacher. The experiments made with the view of discovering the effects of light of various colours on the Iodide of Starch, show that the chemical or blue rays induce the greatest decolorization. (*Vide* page 297.)

Changes of weather.

Decolorization from excess of Ozone?

Light.

F. *Sulphurous Acid in the Air.*

This acid is one of the most common and abundant of the products of combustion. It is, accordingly, found not only in towns, but in the suburbs of the same, and wherever coals are employed as a fuel, and gas as an illuminating agent. It has been calculated that every 100 lbs. of common house coal contain on an average $2\frac{1}{2}$ lbs. of Sulphur, which produces in burning 5 lbs. of Sulphurous Acid. The amount of this acid in smoke varies according to the quantity of air with which coal is supplied. The stone of our public buildings is disintegrated

Proportion supplied by coal.

by it, and the ornaments of our rooms suffer from its effects. I have known tests colour on the windward and bleach on the leeward sides of a town at the same time. So sensitive are ozonoscopes to the decolorizing influence of this acid, that the smallest trace is sufficient to bring about a complete removal of colour. If a coloured Iodide of Starch test be damp or wet, and a minute morsel of soot containing Sulphurous Acid is deposited upon it by air which has become mixed with smoke, a sufficient amount of this Sulphur acid will have been, in all probability, communicated to it to cause speedy decolorization.

Action of soot on a wet Iodide of Starch test.

Experiment.

A deeply coloured Iodized Starch test moistened and then dried by holding it at some height above a gas flame, will be found to lose some of its colour. If again moistened and similarly treated, complete blanching of the test will occur, in consequence of the action of this acid on it. A coloured Iodized Starch test of equal depth of tint, alternately moistened and dried the same number of times *before* a fire, does not become blanched; although, by the loss of its hygroscopic moisture, and by the solution of some of the Iodide of Starch, it may somewhat fade. A Sulphate of Manganese test, which has become brown by exposure to Ozone, constitutes a very ready test for indicating the presence of Sulphurous Acid in air that contains smoke. When particles of soot, even so small as to be scarcely discernible, settle on it, they produce white decolorized spots.

Sulphate of Manganese test.

Decolorization of tests not generally due to Ammonia of the air, or to Sulphuretted Hydrogen.

Dr. Moffat is in error in thinking that the bleaching of coloured tests is generally due to the presence of either Sulphuretted Hydrogen or Ammonia in the air. We shall hereafter see that the latter substance exists in such infinitesimal proportions in pure air, as to be unable to exert any action on ozonoscopes. The tests which he and others have employed to indicate the presence of Sulphuretted Hydrogen in the laboratory, such as the Acetate and Carbonate of Lead with which it forms the brownish-black Sulphide of Lead, are unadapted for detecting it

in the atmosphere, because they are similarly coloured by Ozone which converts the Protoxide into the brown Peroxide. We all are aware that brown and brownish-black colours may easily be confounded with one another. Sulphuretted Hydrogen possesses such a powerful and characteristic odour, as to be recognized with ease even in minute quantities. It is a gas essentially belonging to drains, sewers, cesspools, middens, or heaps of decomposing organic matters, in which situations it is generated. It is uncommonly encountered in other localities. If Dr. Moffat's views, as to this gas being one of the principal causes of the bleaching of tests, were correct, we should expect to find it often in country air which, in truth, is rarely contaminated by it.

G. *True Antozone in the Air.*

The decolorization of tests, which have become coloured during an exposure to the air, has been ascribed by some, in circumstances where it could not have been induced by heat, moisture, etc., to the presence in the atmosphere of Schönbein's Antozone.

Remarks of Dr. Mitchell.

In a paper published in 1860 by Dr. Mitchell,[1] on the imperfections in the mode of determining the amount of atmospheric Ozone, he refers to "the curious fact, that a paper exposed at night may at six or seven in the morning be deeply discoloured, and at nine or ten, the regular hour for the reading, be bleached again. This occurs independently of light or moisture in the air. Its cause I am not able definitely to assign. But, as a source of error, it is of great gravity. It has been asked whether it may not depend on the action of Antozone, but the existence of this body in a free state has not yet been determined."

Because an Antozonide has been said by Schönbein to decolorize certain tests—*e.g.* the Sulphate of Manganese—which have been tinted by Ozone, and to be for

[1] "Remarks on Ozone." *Edinburgh New Philosophical Journal*, New Series, July 1860.

the most part antagonistic in its action to that of an Ozonide, certain observers seem to have assumed that the so-called Antozone would bleach all tests which had been coloured by Ozone. The occasional removal of the tints of coloured ozonoscopes, when exposed to the air, has even been regarded as a proof of the presence of this body in the atmosphere! As the so-called Antozone is shown to be simply the Peroxide of Hydrogen, and as this principle does not decolorize but, on the contrary, tints Iodide of Potassium and Iodized Starch ozonoscopes, we are led to inquire as to whether there is any reason for suspecting the existence of any body in the air antithetical in its nature to that of Ozone.

Does the air contain a body antithetical in its nature to Ozone?

Now and then a bleaching of coloured tests sets in during the prevalence of atmospheric conditions which preclude the supposition that the phenomenon is occasioned by any known agent, such as a high temperature, excessive humidity, Sulphurous Acid, etc. If a portion of an Iodide of Potassium coloured test thus bleached be examined for the Iodate of Potash, an indication of the presence of this substance may be obtained. If the remaining portion of the same slip be exposed for a longer time during the bleaching period and be again tested, it will be found impossible to obtain evidence of even a trace of the Iodate. If a bleached colour test which contains a large amount of the Iodate be enclosed in an envelope and kept in a drawer for a few days, it will no longer be found to exhibit, on re-examination, the reaction characteristic of this salt. It sometimes happens that, in consequence of the brevity of one of these periods, the complete bleaching of the test is not attained. In such cases we find the colourless tests furnish proof of an abundance of the Iodate of Potash. At other times, the process of bleaching is so rapid, that it is almost impossible to detect the intermediate stage during which the Iodate may be found.

Curious changes in coloured Potassium Iodide tests.

The nature of the body which exerts this antagonistic influence on the tests being unknown it has been named, for the sake of convenience only, *true* Antozone, in order to distinguish it from Schönbein's Antozone, with which it has hitherto been erroneously identified.

It has been suggested that this bleaching may be due to Hydrogen gas, which has been found by M. Ramon de Luna to decolorize ozonoscopes.[1] This gas has never yet been shown, however, to exist in a free state in the air. In a paper "On the Estimation of Atmospheric Ozone by means of Aspirators and Acids," which was read at the annual meeting of the British Medical Association in 1871, the various causes of the loss of colour of tinted tests were enumerated and discussed by me. It was therein stated, that sometimes, when the temperature is low and the air is dry, a peculiar state of the atmosphere is observed, during which a bleaching of Iodide of Potassium and Iodized Starch tests, that have been coloured by Ozone and the other air-purifiers, occurs. It seems to be most frequently accompanied by a North wind. Dr. Allnatt of Frant has evidently been long aware of the occasional development of this antithetical condition which he has wrongly attributed to Schönbein's Antozone. He wrote in January 1865—"On the 22d of this month, the day slips exhibited the maximum or 10° of the ozonometer, and during the ensuing night, which was a period of Antozone—clear, calm, with frosty North wind—their colour was discharged fully 6°, and consequently the morning register had dwindled down to 4° of the scale." He adds—"This atmospheric state has been said to play an important part in depriving the air of Ozone—its supposed healthy stimulus. Vitality is said to languish and contagion to spread during one of these periods; moreover, fevers which have for their vehicle the Protocarburet of Hydrogen are widely disseminated." It is certainly very remarkable, that the purifying principles contained in the air

Bleaching ascribed to Hydrogen.

Dr. Allnatt's observations.

[1] *Annales de Chimie et de Physique*, 1863.

should have been almost universally found, except near great Ozone manufactories—such as the sea, forests, etc.—to be at a minimum when the North wind blows; for it is during the prevalence of winds from this point that *true* Antozone periods are most common. Dr. Richardson has performed some experiments, which induce him to believe that Oxygen may exist in an opposite condition to the ozonised state. He made animals re-inhale air many times over, and then removed from it Carbonic Acid and other tangible impurities. He found that "in this negative Oxygen animals die, as if under the influence of a narcotic; in it, the destruction of the products of organic decomposition is greatly impeded, and the presence of such products speedily renders it intolerably offensive; dead animal tissue in it rapidly putrefies, and wounds in the bodies of living animals become sanious, dark, and unwholesome. Ozone at once restores its active power." In a paper by him "On certain Physiological Experiments with Ozone," already referred to, he wrote—"Wounds become unhealthy and heal slowly in *negative air*. There is no demonstrative evidence, as yet, that any diseases are actually caused by it; but the inference is fair, that diseases which show a putrefactive tendency are influenced injuriously by this negative condition of the Oxygen of the air. It is also probable that during this state decomposing organic poisonous matters become more injurious."

Dr. Richardson's experiments and remarks on "Negative air."

Although Dr. Richardson's conclusions are of great interest in connection with this subject, there is no proof that a *negative* state of the air ever occurs in nature, or that coloured ozonoscopes are bleached when suspended in "*negative* Oxygen."

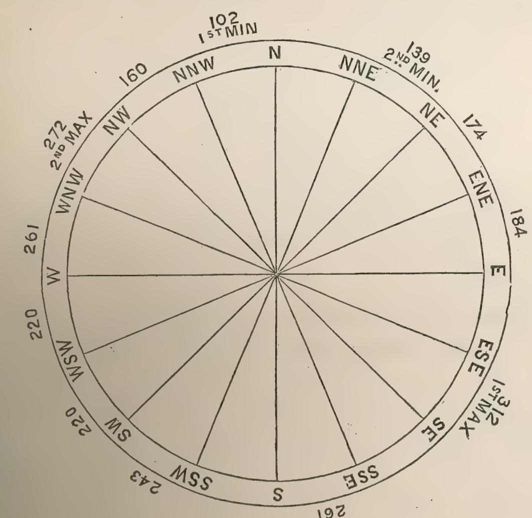
North wind

It is remarkable that a *true* Antozone period should be nearly always accompanied by a North wind. When the intimate relations that subsist between Ozone and Electricity are considered (the electrical discharges, silent and otherwise, which are continually taking place in the atmo-

sphere, being the principal source of this body), it becomes a very interesting question as to whether or not there is any connection between the manifestation of such a period and the quality or tension of the atmospheric Electricity. The following diagram, constructed from the observations of M. Quételet the Astronomer Royal of Belgium, shows[1] that the average annual amount of electric force is at its minimum during the prevalence of winds blowing from a point midway between N. and N.N.W., or between the polar and magnetic North pole.

Minimum electric force with North winds.

PLATE 14.



It will be readily understood that the occasional bleaching of tests which have undergone coloration from exposure to the air, in consequence of the operation of the cause that we have been considering, has not only been an amazing perplexity to observers, but a great source of fallacy.

[1] *Sur le Climat de la Belgique.*

7. *Light.*

The influence of light on Iodized Starch ozonoscopes has been the subject of some contradictory evidence. As the matter is fully discussed at pages 295-298, it is only requisite here to point out the effect of this agent in falsifying the returns of our present very imperfect system of ozonometry. Colourless Iodized Starch tests are browned by the action of light; whilst tinted tests undergo, during a long exposure, some bleaching. Both of these phenomena are due to chemical changes being more readily produced by the blue or chemical than by either of the other rays which, by their union with the blue, form white light.

Chemical changes most readily produced by the blue rays.

As an illustration of the effect of light on colourless tests, we may cite the experiments of Mr. John Atkinson.[1] He divided a colourless Moffat test into two parts, and placed one-half in an Ozone box constructed so as to admit air and exclude all light; whilst the other half was suspended in a thermometer stand, where it was screened from the direct rays of the sun, but unprotected from diffused daylight.

Mr. J. Atkinson's experiments.

Result of Observations from August 1st to 31st, and from September 1st to 24th, 1862.

	In Box.	In Thermometer Stand.
Aug. 1st to 31st, average per day . .	4·2	10·0
Sept. 1st to 24th „ „ . .	3·2	7·6
	7·4	17·6

8. *Ozonometers faulty in Construction.*

Ozonometers, or scales consisting of numbered gradations of colour, are employed as standards of comparison with which the tints of exposed tests are measured. Schönbein and his followers have employed a chromatic scale of 10. Some Frenchmen prefer one divided into

[1] *Proceedings of Meteorological Society*, January 1863.

12 parts, whilst others use the ozonometer of MM. Bérigny and Salleron, which contains 21 shades of colour. In this country, a gradation of 10 is generally adopted.

Many and various are the faults of ozonometers. They may be thus summarized:—

Faults.

(1.) The degrees of colour of different ozonometers, divided into the same number of parts, often do not correspond with each other. I possess two reddish-brown ozonometers, both divided into 10 gradations: the maximum or No. 10 tint of one of them is identical in depth of colour with No. 4 of the other scale.

(2.) Some of the graduations of an ozonometer approach one another so closely, that it becomes almost impossible to distinguish between them. This is especially the case with respect to the ozonometer which accompanies the tests of M. Jame de Sedan.

(3.) The precise shade of the blue, purple, or reddish-brown gradations of the scale is frequently not identical with that assumed by the tests. Sometimes with a box of tests, which become on exposure violet, is supplied a reddish-brown ozonometer.

M. A. Poey, director of the Havannah Observatory, communicated a paper to the French Academy of Sciences on October 28th, 1867, concerning the impossibility of calculating the shades of colour exceeding No. 11 assumed by the tests of M. Jame de Sedan, by a comparison with the graduated scale of MM. Bérigny and Salleron which is supplied with them. This arose from the fact that the tests acquired, under different atmospheric conditions, tints dissimilar from those of the lilac-coloured scale. Sometimes the tests were blue, violet, or bluish-violet. At other times a brown, red, or yellowish colour was observed. He also found that the ozonometers themselves did not agree with one another when compared.

M. Poey's censure.

It is a matter of some difficulty to determine with which of the numbers on the scale the exposed tint corresponds in depth of shade, when the colours are different. Scarcely two people can sometimes be found to agree.

(4.) Lastly, there is the error arising from the fallacies inseparable from the method of observation, which renders it questionable whether one, based on a comparison of tints distinguished from one another by only slight differences, can be made scientifically exact. A great many people, if not colour-blind, cannot discriminate between shades of colour closely resembling although distinct from one another, so as to be able to refer the test paper to the exactly corresponding shade upon the scale. With reference to this subject, Dr. Mitchell writes—" It often happened that on comparing the tint of the test with the scale, I myself assigned to it one number, while another person placed it a degree higher, and a third a degree lower, whilst, occasionally, even a greater diversity than this occurred, amounting to about 30 per cent."

Osann of Würtzburg.

Professor Osann of Würtzburg and others have attempted to render ozonometry more accurate, by increasing the number of degrees of an ozonometer, and by arranging them on a movable screen. The shades are thus made to pass successively before the coloured test paper. A more exact determination of the shade with which the exposed test corresponds is thought to be by these means attained.

9. *Differences of Aspect and Elevation.*

Aspect.

It has been found that an ozonoscope exposed to the North exhibits a deeper tint than one suspended in a situation where it has a Southerly aspect, the duration and height of exposure being of course the same in both cases. Schiefferdecker has noticed that the tint of a test paper is different when the aspect is East, from that which is observed when it is exposed to the West.

Elevation.

It has been already shown (page 102) that the degree of elevation of ozonoscopes above the ground makes a considerable difference in their indications. Tests have hitherto been suspended by observers at various heights, without any regard whatsoever to uniformity.

The Action on Ozonoscopes of Bodies which have been declared to influence them when present in the Atmosphere.

The majority of readers will, in all probability, have arrived at a disheartening conclusion, after a perusal of the foregoing pages, with respect to the value of past observations with the Iodized Starch test. Let us not hastily condemn them, but carefully examine the evidence *pro* and *con.* the belief in the presence in the air of each of the following agents, which have been thought to set free the Iodine from the Potassium Iodide, and at the same time investigate for ourselves their action on this salt:—

1. Light.
2. Peroxide of Hydrogen.
3. Carbonic Acid.
4. Sulphuric Acid. Sulphurous Acid. Sulphates.
5. Sulphuretted Hydrogen.
6. Iodine. Bromine.
7. Nitric Acid. Nitrous „ Nitrates. Nitrites.
8. Essential oils, etc.
9. Formic Acid.
10. Dusts.
11. Chlorine. Hydrochloric Acid. Chlorides.
12. Ammonia.

Necessity for the inquiry.

Although an examination of the effects of all these bodies on ozonoscopes is somewhat laborious, it is needful that such should be made, in order that the ozonometry of the future may be placed on a thoroughly stable foundation, and that we may ascertain the exact worth of past Ozone records.

1. *Light.*—Its influence on ozonoscopes is fully discussed on pages 295-298.

2. *Peroxide of Hydrogen.*—As this principle is, in all probability, sometimes present in the atmosphere (*vide* article " Does the air contain Antozone, *alias* the Peroxide of Hydrogen?" page 51), it is necessary to observe its influence on the ozonoscopes that have hitherto been em-

ployed. Most ozonographers have noticed that periods sometimes occur when colourless ozonoscopes do not tint, whilst those which are coloured become bleached. This decolorization has been erroneously ascribed to the presence of Schönbein's Antozone in the air, which body has proved to be simply the Peroxide of Hydrogen. Now, oxygenated water, although a powerful bleaching agent, does not remove the colour from the Iodized Starch or Potassium Iodide tests which have been tinted by Ozone; on the contrary, it increases their colour, if applied to either of these tests in the form of a fine spray. Houzeau conducted some years ago two series of experiments on Peroxide of Hydrogen, which he introduced to the notice of the French Academy in 1868.[1] He was induced to study it by a desire to discover—(1) some simple and efficient mode of determining minute quantities of this compound; and (2) whether or not his Iodized Litmus ozonoscopes were affected by this body, supposing it to be present in the atmosphere. In the latter series he operated on dew collected far away from towns during nights characterized by a deep test-reaction. He came to the conclusion that Iodized Litmus papers are not tinted by the Peroxide of Hydrogen. He did not, unfortunately, make any observations for the purpose of deciding as to whether the coloration of the Iodide of Potassium or Iodized Starch tests on exposure was at any time partly due to its existence in the air. As there can now be very little doubt but that oxygenated water occurs in the atmosphere in a diluted state, we must admit, remembering its action, that these tests are probably coloured by it.

Houzeau's experiments.

3. *Carbonic Acid.*—The late Dr. R. D. Thomson affirmed, and his statement has been endorsed by Dr.

Drs. Thomson and Day's statement.

[1] "Méthode pour doser et rechercher de Petites Quantités d'Eau Oxygénée"—*Compt. Rend.*, January 6, 1868.

"Sur l'Eau Oxygénée considérée comme n'etant pas la cause des altérations que l'air atmosphérique fait subir aux papiers de tournesol mi-ioduré, employés comme réactifs de l'Ozone"—*Ibid.* February 17, 1868.

Day, that this gas, in its nascent form, colours *highly sensitive* tests.

Experiments.

Some Carbonic Acid was prepared by means of Carbonate of Soda and Tartaric Acid, and precautions were taken to prevent either of these chemicals from being transported by the gas into a receiver, containing a 15 per cent Potassium Iodide, a Schönbein's and a Lowe's test. Neither of these tests exhibited any change after an exposure to this undiluted Carbonic Acid gas for eighteen hours. A stream of Carbonic Acid was allowed to play on each of the three kinds of tests just named for five minutes, but no effect was produced on either of them. They were also uninfluenced by a solution of Carbonic Acid in water. Although Schönbein's and Lowe's tests cannot be called highly sensitive, the simple Potassium Iodide test which was employed is as sensitive as ozonoscopes can conveniently be made (*vide* page 242). Remembering, then, that the normal amount of Carbonic Acid in pure air ranges, according to one authority, from ·0332 to ·0336 per cent, and, according to another, from ·02 to ·05 per cent, we have nothing to fear from this gas. The results arrived at by Drs. R. D. Thomson and Day are explicable only on the supposition that the Potassium Iodide, of which their tests were manufactured, contained impurities. M. Payen has shown that, when Carbonic Acid gas is passed for four hours through a saturated solution of Potassium Iodide, possessing a slight alkalinity and containing a little free Iodine, this salt is decomposed and, if Starch be present, a blue Iodide of Starch is formed. A current of atmospheric air produced in five hours similar results, but, when deprived of its Carbonic Acid, no effect was discoverable. Pure Potassium Iodide subjected to a repetition of these experiments was unaffected. Houzeau also found that an atmosphere, artificially and strongly impregnated with Carbonic Acid gas, did not exert any action on neutral Potassium Iodide exposed to its influence during six weeks.

Amount in pure air.

M. Payen.

4. *Sulphuric Acid, Sulphurous Acid, and Sulphates.*—Rain, which is nature's air-washer, is neutral when it falls in the country. Town rain is generally acid, from the presence of Sulphuric and Sulphurous Acids, arising from the burning of coal, gas, etc. These acids confer upon it its well-known property of corroding metals, stones, and bricks. Sulphuric Acid reddens Potassium Iodide and Iodized Starch tests, whilst Sulphurous Acid, even in minute quantities, removes, with the greatest facility, the colour of tests that have been influenced by an exposure.

Sulphates. Sulphur compounds are found in the atmosphere in situations where they cannot be attributed to the combustion of fuel. The "dust of the sea," carried as it is for many miles inland, contains Chlorides and Sulphates. Whence arise the Sulphates found in air far away from the sea, from towns, and from manufactories?—Doubtless as a result of the decomposition of animal and vegetable matters. M. Pierre thinks that Sulphates are formed in the air from Sulphuretted Hydrogen. Have, then, the Sulphates of Magnesia and Lime contained in sea-water, or the Sulphate of Ammonia—the Sulphur salt most likely to be present in inland air—any effect in the form of spray or solution on Iodized Starch, or 10 per cent Potassium Iodide tests?—None whatever.

The acids are, of course, avoided by conducting our observations in situations free from smoke, and far removed from all villages, towns, and centres of manufacturing industry.

5. *Sulphuretted Hydrogen and other products of Putrefaction.*—It is the opinion of Dr. Moffat that the bleaching of tests is generally due to the influence of Sulphuretted Hydrogen. He seems to base it on the fact that the colour of tests is removed when they are suspended close to cesspools. Sulphuretted Hydrogen in a concentrated form does undoubtedly blanch tests; but I certainly cannot admit that bleaching is owing to the presence of this gas, when the change occurs in places far removed

from all decomposing animal or vegetable matter. Dr. Allnatt very truly observes—"In the mephitic atmosphere of crowded cities, or in malarious localities, this might be; but on the high ground of Frant (whence my observations date) the supposition could not apply, as the altitude is beyond that of Beachy Head." Tests are influenced by other products of putrefaction besides Sulphuretted Hydrogen, from which emanations they cannot be too carefully protected. Dr. Allnatt.

6. *Iodine and Bromine.*—Great difference of opinion prevails as to whether Iodine does or does not exist in the air. In the *Handwörterbuch der Chemie* of 1864 we find a record of the contradictory results arrived at by chemists—"Chatin and E. Marchand assert that rain and snow contain Iodine. Chatin says that he found it in rain in different parts of France, amounting to 1 milligram (·0154 gr.) in 20 litres (676·3 fl. oz.); less in Pisa, Lucca, and Florence; whilst he discovered none in rain on the St. Bernard and Splügen, or in the glacier water from Mont Cenis and Norway." De Luca collected rain water on the summit of the leaning tower of Pisa on several days at different seasons of the year, evaporated it carefully to dryness with pure Carbonate of Potash, and then tested for Iodine. He did not find in any instance a trace. "Mène gives the same view. Casaseca found in the rain of Havana no Iodine." Chatin and E. Marchand. De Luca. Mène. Casaseca.

Iodine and Bromine have been thought to be present in a free state in the marine atmosphere, in consequence, it would appear, of the similarity between the odour of sea air and that of these elements. I do not know that any investigator has proved the presence of Bromine in the air, although certain chemists have found it in minute quantities as a Bromide of Magnesium in sea water. Berzelius states that sea water contains also traces of Iodide of Sodium. Seaweeds have been shown to contain about $3\frac{1}{4}$ lbs. per ton. In some species of Laminaria Iodide of Sodium exists to the extent of 5 per cent of the Iodine and Bromine in sea water. Iodine in sea and land plants.

ash. Iodine has been detected by Macadam in as many as sixty of our indigenous land plants. The question then arises—Where do these plants obtain it, if it is absent from the soil, as some have declared? At any rate, if Iodine ever exists in a free state in the air, its amount is so infinitesimally small as to be practically powerless over Iodized Starch or Potassium Iodide tests.

7. *Nitric and Nitrous Acids, Nitrates and Nitrites.*—

(*a*) Nitric Acid.

Nitric Acid has been observed in rain by several distinguished men, such as Boussingault,[1] Barral, and Bineau. It is said to be especially abundant in the rain of thunderstorms, the passage of the electric discharges through the air producing a union of two of its constituents.

Marggraf.

Marggraf proved its existence in snow in 1750.

Priestley.

Priestley demonstrated, at the end of the last century, that the gaseous elements of air—Oxygen and Nitrogen—can combine under the influence of an electric spark, when they are moist, so as to form Nitric Acid.

Liebig.

Liebig in 1827 obtained and analysed seventy-seven samples of rain water collected in porcelain vessels. Seventeen samples out of the seventy-seven fell during storms. Liebig found in these seventeen Nitric Acid in greater or less quantity, combined with Lime or Ammonia. In the other sixty samples of rain he only discovered two in which traces of Nitric Acid existed. Admitting, then, its presence in rain, the important question arises—Does Nitric Acid exist in the air in an uncombined form? It is certain that some acid is occasionally present in the air of the country.

Boussingault.

Boussingault declares[2] that he has found in dew arising from the condensation of atmospheric humidity a proportion of Ammonia, much larger than that which was sufficient to saturate the Nitric Acid also estimated in this liquid. This fact has induced scientific men to think that this acid may not exist in a *free* state in the air.

[1] *Compt. Rend.*, tom. xlvi., 1123 and 1175.
[2] *Sur les Eaux Meteoriques.*

Houzeau's experiments.

To ascertain whether the chemical activity of the air is occasioned by the presence of a Nitrogen acid, Houzeau exposed large surfaces of calico impregnated with a solution of Bicarbonate of Soda to pure air, when sensitive and slightly sensitive test papers became deeply tinted.

	Milligram = ·0154 gr.
Quantity of Nitric Acid found in the alkaline handkerchief *exposed* 24 hours to very active air . .	·015
Quantity of Nitric Acid found in the alkaline handkerchief *not* exposed to the air	·011
Difference comprised within the limits of error . .	·004

He then exposed these same absorbing surfaces to the action of an atmosphere artificially mingled with Peroxide of Nitrogen to the extent of ·00005 of its volume. In this mixture a test feebly sensitive did not change, but a sensitive test on the contrary became strongly tinted.

	Milligram = ·0154 gr.
Quantity of Nitric Acid found in the alkaline handkerchief *exposed* 24 hours to air artificially mixed with a Nitrogen compound	1·486
Quantity of Nitric Acid found in the alkaline handkerchief *not* exposed	·011
Nitric Acid . . .	1·475

The results of Houzeau's experiments have led him to form the opinion that no observations of any weight prove the existence of Nitric Acid, and especially its persistence in a free state in the air. The evidence as to the depth of coloration assumed by the Iodized Starch test when exposed to the air during thunderstorms is given on page 70.

Is *free* Nitric Acid ever found in the air?

To ascertain whether any *free* Nitric Acid was to be detected in the air, during periods when it is most likely to be present, I performed the following experiment with a modification of Andrews' globe apparatus, described on pages 47 and 48.

Having first convinced myself that Nitric Acid, when

mingled even in minute quantities with the air which was drawn through the apparatus, almost instantaneously coloured a 15 per cent Potassium Iodide test paper, I determined to make air traverse it, when evidence was

PLATE 15. *Modification of Professor Andrews' Globe Apparatus.*

Apparatus employed to decide the question.

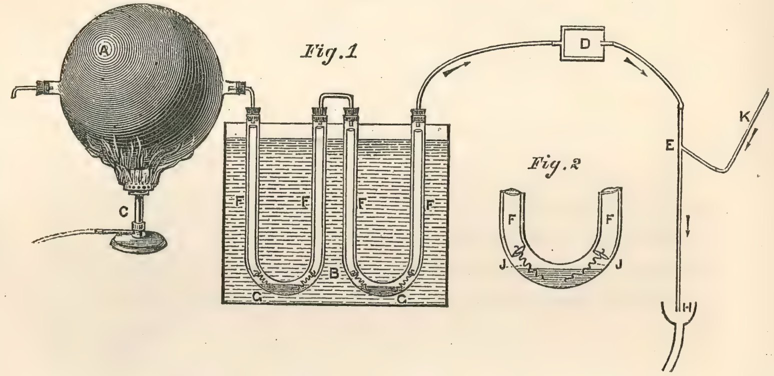


Fig. 1.

A, Glass Globe (5 litres) covered with copper gauze.
B, Tank of cold water.
C, Bunsen's Burner.
D, Ozone Box.
E, A Tube Aspirator.
FF, Tubes lined with bibulous paper.
GG, Layers of Distilled Water at bends of tubes.
H, Exit Tube for discharge of Water from Aspirator into sink.
K, India - rubber Tube from Water Tank.

Fig. 2.

Enlarged Representation of Bend of Tube F.
FF, Tubes of bibulous paper through which the air passes, which are connected with a layer of water, by means of
JJ, Lamp Wicks.

afforded of the occurrence of frequent atmospherical discharges of electricity, accompanied by a deep test-reaction. If, I argued, a test becomes coloured at such a time by air which has before reaching it been heated to about 570° Fahr. (at which temperature Ozone is instantaneously reconverted into Oxygen) and subsequently

restored, as completely as possible, to its original temperature and degree of humidity, it must be concluded that Nitric Acid is concerned in the coloration. But if, on the other hand, no change in the tests should occur during the maintenance of this high temperature, it may then be safely inferred that the tinting of the ozonoscopes in the open air is not due to its presence. Instead of employing one U tube moistened internally with water, as recommended by Andrews, I found that moisture was more readily restored to the excessively hot air, and the temperature was more rapidly reduced by passing it through two U tubes (each a metre in length) lined with bibulous paper, and having at their bends little reservoirs of water to maintain the paper in a moist condition.

Experiment during a long thunderstorm.

On July 8th, 1871, at mid-day, a thunderstorm visited Scarborough, which was followed for several hours by frequent electrical discharges. Wind S.W. As soon as the air in the globe had reached to a temperature of about 570° Fahr., a 15 per cent Potassium Iodide test was placed in the Ozone box to ascertain whether or not any Ozone passed through the apparatus unacted upon. Having convinced myself of its complete reconversion into Oxygen, the experiment was commenced and carried on for five consecutive hours, the air passing through the aspirator at the rate of 4700 cubic inches per hour. Tests, precisely similar, were suspended in the open air during the continuance of this experiment. At its termination, the test from the Ozone box was colourless, and the ozonoscopes which had been exposed to the air possessed a strong reddish-brown tint.

If Nitric Acid be produced during thunderstorms, which seems extremely probable, its diffusion through such an enormous mass of air may render the amount so infinitesimal at the earth's surface as to be inappreciable to the most sensitive tests at our command. An aqueous precipitation may possibly be necessary in order to bring it down from the elevated regions in which it has been

generated. At all events, we have seen in this experiment that the Potassium Iodide tests exposed to the air acquired a colour, notwithstanding the absence of an appreciable amount of Nitric Acid, during a period when this acid is more likely to be found in the atmosphere than at any other.

M. Pouriau's observations. M. Pouriau, Professor of Physical Sciences in the Imperial School of Agriculture of Saulsaie (Ain), has found [1] that rain is most rich in Nitric Acid when the coloration of ozonoscopes is at a minimum, and *vice versâ*.

The conclusion, then, which we are compelled to arrive at is that Nitric Acid is not appreciable in a *free* state in the atmosphere; but that it, in all probability, combines at the moment of its formation with Ammonia or some other base.

Conclusion.

(*b*) Nitrous Acid. *Nitrous Acid* or Hyponitric Acid (NO_2 or N_2O_4), named more recently Nitrogen-Peroxide or Nitric Peroxide, is said to be the only compound of Oxygen and Nitrogen, besides Nitric Acid, which can be supposed to exist in a free state in the air, so great is the instability of the other Oxides.

The Nitric Peroxide, or Nitrous Acid as it will be called for the sake of convenience throughout this work, is stated by chemists to be decomposed by moisture into Nitric Acid and the Deutoxide of Nitrogen (now called Nitric Oxide). This Deutoxide is neither acid nor alkaline, but has a powerful affinity for Oxygen. On coming into contact with the air, it produces dense red fumes freely soluble in water with which they form an acid liquid. This fluid contains the Peroxide of Nitrogen or Nitrous Acid, associated probably with a small quantity of Nitric Oxide or some other allied compound. Air containing this acid reddens Blue Litmus and decomposes Iodide of Potassium.

Although a number of chemists have shown that the passage of the electric spark through *pure Oxygen* is attended by the production of Ozone, Cavendish long ago pointed out that when it is transmitted through the *air* Nitrous Acid is formed.

[1] *Études Météorologiques Relatives au Climat de la Saulsaie.*

Cavendish.

M. Morin. The experiments of M. Morin, described on page 110, not only show that Ozone may be manufactured by the dispersion through the air of water in a pulverized condition, but that the formation of active Oxygen is accompanied by the development of an acid which is, in all probability, a compound of Nitrogen. We have been unable to detect Nitric Acid in a *free* state in the air. Nitrous Acid is the only other stable Nitrogen acid.

M. Cloez. The researches of Cloez, already referred to (page 46), concerning the presence of Nitrous Acid in the atmosphere, and the facility with which even the minutest quantity influences the Iodized Starch test, are very important. He, as well as Sterry Hunt,[1] Sauvage,[2] Böttger, J. Day, Rivier, Professor Fellenburg,[3] and many others, believe that the reactions attributed to Ozone are due in part to Nitrous Acid. The two last-named observers affirm that pure Nitric Acid, when very much diluted, does not render blue a mixture of Iodide of Potassium and Starch, which reaction is readily produced by Nitrous Acid.

Other observers.

M. Chabrier. M. Chabrier, who has made [4] some recent observations on the alternate predominance of Nitrous Acid and of Nitric Acid in rain water, has found that, when the weather is calm and storms are at a distance, Nitrous Acid is almost always in excess in rain; and that the quantity of Nitric Acid is, on the other hand, greater than that of Nitrous Acid in rain attended by storms or by powerful winds. He thinks that those seasons are favourable to the production of Nitrous Acid which are characterized by calm and overcast weather, by a mean temperature

[1] "Ozone, Nitrous Acid, and Nitrogen:" *American Journal of Science*, vol. xxxii. No. 94.

[2] *Comptes Rendus*, 1868.

[3] *Archives de l'Electricité*, No. 17, tome v., 1845.

[4] *Compt. Rend.*, November 27, 1871.

and a large amount of moisture in the air; and that those seasons promote the formation of Nitric Acid, which are accompanied by an elevated temperature, a violent agitation of the air and dry stormy weather.

That Nitrous Acid is one of the agents concerned in the coloration of the Iodized Starch test, can scarcely any longer be denied.

(*c*) Nitrates. The *Nitrates and Nitrites* have been regarded, like the Nitrogen acids, as being concerned in the coloration of the ozonoscopes.

The quantity of Nitrates formed in the air by the union of the Nitric Acid and Ammonia is very large.

M. Chabris. M. Chabris has recently calculated[1] that as much as three pounds per acre are annually carried down to the soil by the rain for the nutrition of plants. The amount of this salt is particularly great after storms. M. Sainte-Claire Deville collected a few years ago rain and snow water amongst the Alps, which was analysed by M. Boussingault. He found

In a litre ($35\frac{1}{4}$ fl. oz.) of water

Alpine snow.

	Ammonia.	Nitric Acid.
Snow from St. Bernard .	traces	traces.
Rain „ „	1·10	·30 milligram.*
Snow „ Mont Combin (14,534 ft.) after a violent storm .	11·00	22·00 „

* A milligram = ·0154 grain.

M. Cloez. Cloez discovered that the Oxygen and Nitrogen of the air will unite, so as to slowly form Nitrates and Nitrites, when they are brought into contact with porous bodies moistened with alkaline solutions. Precautions were of course taken by him in his experiments to ensure the absence of any Ammonia which might be present in the air operated on.

[1] Communication to French Academy of Sciences, August 21, 1871.

M. de Luca[1] has, in fact, prepared the Nitrate of Potash, by passing very slowly damp ozonised air, previously freed from any foreign bodies or compounds of Nitrogen which it might contain, over Potassium and pure Potash. M. de Luca.

Schönbein assures us that the evaporation of water is accompanied by the formation of Nitrate of Ammonia. He says that a sheet of filtering paper, or a little sand, dipped in pure water and dried in the air, becomes impregnated with this salt, in quantity sufficient to be easily distinguished in the water with which either of these substances is washed. Schönbein.

Rivier and Fellenburg conclude, from their experiments, that the Nitr*a*tes are formed from Nitr*i*tes by the absorption of Oxygen during the evaporation. Rivier and Fellenburg.

Professor Struve and other investigators recognize the presence in the air of Nitr*a*tes, but are silent as regards Nitr*i*tes. The Nitrates of Potash and Ammonia have no effect on Potassium Iodide or Iodized Starch tests when dipped in a solution of these salts, or when a solution is applied in the form of spray. The Nitrite of Potash, however, does influence most ozonoscopes in a manner which cannot without much difficulty be distinguished from the action exerted on them by Ozone. Are Nitrites ever found in the air? The experiments of M. Bobierre of Nantes, of Mr. Dancer, and others, furnish us with good reasons for believing that the Ammonia, evolved as a result of the decomposition of animal and vegetable substances, becomes oxidized along with the organic matter which is constantly floating in the air as they rise into the higher regions of the atmosphere; and that their conversion into Nitrates does not begin until they reach about five or six feet above the ground. Now, although the Ammonia in such minute quantities as are found in the air has no effect on the tests, and Nitr*a*tes do not influence them, be they in large or small amount, it is just possible Professor Struve. (*d*) Nitrites. Experiments of M. Bobierre and Mr. Dancer.

[1] *Philosophical Transactions*, t. lxxv. and lxviii.

that some Nitr*i*tes may be at the same time formed, which, by their action on the papers, simulate that of Ozone.

Böttger.

Böttger[1] affirms that Nitrite of Ammonia is a constant product of all combustion in the air, and that an appreciable quantity of it, or of Nitrous Acid, is produced by the evaporation of water.

Gorup-Besanez.

Gorup-Besanez declares[2] that Ammonium Nitrite is formed in conjunction with Ozone by aqueous vaporization, and is found in sensible quantity in the air. He states that this salt is quite unable to decompose the Potassium Iodide of the Iodized Starch test. Huizinga has asserted[3] that the Nitrite of Ammonia, under the influence of Carbonic Acid, will decompose Potassium Iodide. He passed a current of the gas through a solution of the Nitrite, over which was suspended an Iodized Starch test, and found it coloured. Gorup-Besanez contends, however, that, if the Carbonic Acid be perfectly free from Sulphuric Acid and any other impurity, this effect is not produced.

Huizinga.

8. *Essential Oils, Terebinthinate and Aromatic Exhalations of Plants.*—MM. Cloez and Bineau think that the volatile substances which plants furnish to the air are one cause of the coloration of ozonoscopes. Cloez, having assured himself by some experiments already alluded to (page 119), that the Oxygen liberated from the leaves of plants does not affect the tests, placed on the plain of Picardy, where there is not a tree within a radius of 9842 feet, a test paper affixed to the extremity of a stick plunged into the ground. At about 13,123 feet from this spot, in a park containing trees, he suspended another test. At the end of four hours the latter had acquired a very distinct brownish-violet colour; whilst that on the plain was still perfectly colourless, even after an exposure of two days. M. Gury confirmed this experiment by the performance of one precisely similar near

Experiments of M. Cloez.

Of M. Gury.

[1] *American Journal of Science*, 2d series, vol. xxxv., 1863.
[2] *Op. cit.* [3] *Journ. f. Pract. Chem.*, 102, 193.

Metz, which was attended with a result still more striking. The exhalations from resinous trees and aromatic plants, in fact from all those parts of plants which yield the essential oils in distillation, are considered by Cloez to be especially liable to impart to the air the power of affecting the Iodized Starch test in the same manner as Ozone, without ozonising the atmospheric Oxygen.

Dr. Daubeny's advice.

Dr. Daubeny gives the following words of advice to Ozone observers:—"Exclude the influence of volatile Hydrocarbons and aromatic flowers and plants, some of which, like oil of turpentine, seem to unite loosely with Oxygen and then furnish indications of Ozone."

Mantegazza.

The investigations of Mantegazza (*vide* pages 121 and 122) show that Ozone is emitted from odoriferous flowers under the influence of light and the Oxygen of the air, whilst those without scent produce none. We all know that tests exposed to the vapour of the essence of turpentine, to the oils of lavender, juniper, rosemary, sassafras, etc., become discoloured in various degrees. The question as to whether the odours and exhalations of plants affect ozonoscopes has been carefully examined by Professor W. B. Rogers.[1] After a number of experiments on coniferous and highly odoriferous plants, he came to the conclusion that the influence of terebinthinate or other odours, as they are exhaled in the open air from plants, is either entirely insensible, or so slight as not to interfere with the accuracy of the test as a measure of atmospheric Ozone.

Rogers' investigations.

9. *Formic Acid* is so rarely and in such infinitesimal amounts found in the air, that it may safely be disregarded.

10. *Dust.*—The only common kind of dust that interferes to any important extent with the indications of the ordinary Iodized Starch tests is that composed of particles of soot. (*Vide* page 200.)

11. *Chlorine, Hydrochloric Acid, and Chlorides.*—Ozone tests having been found by observers to be more

[1] *Edinburgh New Philosophical Journal*, January 1858.

(a) Chlorine.

deeply tinted during the prevalence of winds from the sea than during the continuance of land breezes, the late Dr. Barker and others have thought that this gas is present in a free state on the sea shore, arising from the decomposition of the Chlorides which are so abundant in the "dust of the sea." Chlorine, even in the smallest quantity, will instantly tint ozonoscopes. Having often myself noticed the excessive discoloration during E. and N.E. winds in Scarborough, it seemed to me of the utmost importance to ascertain if any *free* Chlorine exists in the air, when these sea winds are violent and Ozone tests assume their maximum tints. I have, on these occasions, passed air for many hours, with the assistance of an aspirator, through a solution of Nitrate of Silver, guarding against the intrusion of any Chlorides by allowing the entering air to filter through cotton wool; but have never noticed any turbidity indicating the presence of Chlorine. The experiment described on pages 216 and 217 was also repeated on a day in June 1871, during which a stiff sea breeze from the N.E. was blowing. A very delicate 15 per cent Potassium Iodide test was placed in an Ozone box in connection with the globe apparatus there depicted, and about 2350 cubic inches of air were drawn over it. This quantity of air gave a tint of No. 3 of the chromatic scale. The globe was then raised to 570° Fahr., and a fresh test was inserted in the box. A test of the same strength was also placed in an Ozone box attached to another aspirator, precisely similar to that employed in conjunction with the globe. This experiment was carried on for three hours, at the end of which time 14,100 cubic inches of air had passed over each test. The slip removed from the apparatus was found colourless, whilst that taken from the Ozone box unconnected with the globe was strongly tinted. The excessive coloration of Ozone tests during a sea breeze is not due to the action of Chlorine; for, if the slightest trace of this gas had been present in the air, the test paper

Does this gas exist in a *free* state in the air?

Experiments.

Conclusion.

in communication with the globe apparatus would have been tinted, notwithstanding the high temperature. A more exact conclusion would perhaps be that, if Chlorine ever does exist in a free state in the air, the most sensitive tests fail to detect it at a time when, above all others, it is most likely to exist in the greatest quantity.

(b) Hydrochloric Acid.

The fumes of Hydrochloric Acid will undoubtedly colour ozonoscopes. It has never yet been shown that Hydrochloric Acid ever exists in an uncombined form in country air, far away from manufactories, chemical works, and towns where coal is burnt. There is every reason for thinking that it never occurs in a free state in pure country air, for the rain which falls through such air is neutral.

(c) Chlorides.

The Chlorides, which form so large a proportion of the "dust of the sea," are said to influence ozonoscopes.

Analyses of sea water.

Schweitzer[1] states that in 1000 parts of sea water the following proportions of the three kinds of Chlorides found in it are present in that of the British Channel. Usiglio's[2] analysis of the water of the Mediterranean is very similar.

	In 1000 parts.	
	British Channel.	Mediterranean.
Chloride of Sodium .	28·05948	29·424
Chloride of Magnesium .	3·66658	3·219
Chloride of Potassium .	·76552	·505

Strong solutions of these salts have no effect on colourless or coloured Potassium Iodide and Iodized Starch tests when applied to them separately in the form of a fine spray.

Sea water has been sprayed by Dr. Day of Stafford over tests with negative results. I have repeated the experiment with the most delicate tests and have found them unchanged thereby.

12. *Ammonia.*—Saussure and Liebig[3] showed, in

[1] *Phil. Mag.*, 1839, vol. xv. p. 58.
[2] *Ann. de Chimie*, III. xxvii. 104.
[3] *Die Organische Chemie in ihrer anwendung auf Agricultur und Physiologie*, S. 64-72.

1840, that the air contains traces of ammoniacal compounds. According to the elaborate researches of Ville, which were conducted in 1851 and 1852, there are only about 224 parts of Ammonia in 10,000,000,000 parts of air. Dr. Angus Smith states[1] that the inland country places of England contain on an average

Proportion in the air.

1·070 parts per million of Ammonia, and
·108 parts per million of Albuminoid Ammonia.

———

1·178

Results of other Analyses as to the Amount of Ammonia in the Air.[2]

		Milligram (·0154 gr.)		Authority.
		·42	in a cubic metre (35·3 cub. ft.)	M. Grager.
		4·78	„ „ „	M. Kemp.
		·17	„ „ „	M. Fresenius.
Of Exps.	1st series	4·5	„ „ „	M. Pierre.
	2d „	·65	„ „ „	M. Pierre.

Although these chemists differ as to the amount of Ammonia present in the atmosphere, the majority agree in attributing to it the possession of a very minute quantity.

The occasional bleaching of tests that have undergone coloration from exposure to the air has been ascribed to the action of Ammonia. Others have declared that ozonoscopes are simply unaffected when air contains an excess of this alkali in the neighbourhood of fields over which manure has been scattered, and that the oxidizing action of Ozone is suspended by the formation of the Ozonide of Ammonium. A 10 per cent Potassium

[1] *Seventh Annual Report under the Alkali Act*, 1871, page 38.

[2] "Different substances which are generally found in variable proportions in Air and Rain"—from *Chimie Agricole*, by M. J. I. Pierre.

Experiments.

Iodide test, which had been deeply tinted by Ozone, was placed over the mouth of a bottle containing some very strong Liq. Ammoniæ, sp. gr. ·880. The bottle was held in a warm hand, so as to encourage the exit of the ammoniacal fumes. A faded spot appeared after an exposure of two or three minutes. On removing the test from the mouth of the bottle, the colour of the spot was in a few moments restored. A *dry* coloured Iodized Starch test was unaffected by the powerful fumes of this liquor. When a *moist* coloured Iodized Starch test was similarly treated, a removal of colour, which was partially recovered on its withdrawal, occurred. A repetition of the process of alternately moistening the test with distilled water, and exposing it to the strongest solution of Ammonia, led to a permanent bleaching. A damp coloured Starch test suspended in an atmosphere so strongly ammoniacal as to be quite irrespirable was quite uninfluenced. A coloured 10 per cent Potassium Iodide test was divided into two parts, one part being wetted with the spray of distilled water, whilst the other was treated with the spray of Liquor Ammoniæ. No difference was observable in the appearance of the parts thus experimented upon. Country air, or that which is free from the impurities forming the air-sewage of towns, has been said to contain Ammonia in the form of the Carbonate. If similar experiments be performed with a strong solution of this salt, or with the Sulphate of Ammonia, no effect will be noticed on the colour tests.

These experiments show that the bleaching of coloured ozonoscopes cannot be due to the Ammonia which exists in the air in minute quantities as one of the products of organic decomposition.

Conclusions.

The result of our consideration of the effects on the Iodized Starch and Potassium Iodide tests of the various bodies, which have been said to operate upon them when exposed to the air, proves that these tests do not indicate the presence of Ozone solely, but that they are also in-

fluenced by Light, Sulphuric and Sulphurous Acids, Peroxide of Hydrogen, and Nitrous Acid. M. Cloez hence concludes that ozonometric observations are entirely without value—"N'ont aucune espèce de valeur." As the Sulphur acids represent manufacturing activity and the decay of organic matters, the test papers will probably have been alone interfered with by them at stations in close proximity to dense masses of people and manufactories consuming coal and gas. Gorup-Besanez thus sums up the most recent advances that have been made by the foremost German *savants*. After expressing the opinion that Nitrous Acid is only occasionally met with in the air, he writes:—"According to our present knowledge, Ozone, the Peroxide of Hydrogen, and Ammonium Nitrite, form a triad in the atmosphere. When one is found, the others are to be recognised." We have already seen that Ammonium Nitrite does not affect ozonoscopes.

Only one conclusion can be arrived at after a careful examination of the foregoing evidence.

As an indicator of the amount of atmospheric Ozone, the Iodized Starch test is evidently untrustworthy and fallacious. Regarding it as an imperfect informant of the amount of purifying principles—viz. Ozone, Peroxide of Hydrogen, and Nitrous Acid—contained in pure air, I cannot but consider it as of some service.

Peroxide of Hydrogen.

Peroxide of Hydrogen is one of those powerful chemical agents which are concerned, like Ozone, in the maintenance of the purity of the air. No known substance surpasses Hydroxyl, as Dr. Frankland calls it, as an oxidizing agent. Professor Taylor says—"The Oxygen contained in it amounts to 94 per cent by weight, and, according to Pelouze, in its maximum of concentration it will give off 475 times its volume of this gas. It has been employed as "a disinfectant" in sick rooms, in the form of spray, with the greatest advantage, but is somewhat expensive for this purpose. It rapidly destroys all noxious gases, and is persistent in its action. The bodies

of patients affected by the eruptive fevers are, by some physicians, bathed with it; whilst the clothes and letters of the sick are cleansed by sprinkling over them this oxygenated water. Dr. Day of Geelong believes that it possesses the power of oxidizing and annihilating the poisons of small-pox, scarlet fever, and typhoid fever.

Nitrous Acid.

Nitrous Acid is considered the most valuable gaseous "disinfectant" and deodorizer that is known. It acts most energetically on organic impurities, removing the unpleasant odours of the deadhouse more readily than any other gas. This rapid action arises from the facility with which it gives up one of its equivalents of Oxygen to any oxidizable substance, being converted into the Binoxide of Nitrogen which directly combines with another atom of Oxygen from the air, which is again yielded up, and so on. The utility of this acid, when diffused through cholera and fever wards, has been attested by medical men in this country and on the Continent.[1] An instrument improperly named an Ozonogene, in which this gas is generated by means of Nitric Acid and Copper turnings, has been employed for such purposes.

Sulphurous Acid.

Sulphurous Acid, which is so abundant in towns, is said to be a powerful antiseptic. It unhappily removes atmospheric impurities at the expense of the "vital air" or Oxygen. This acid, when in contact with moisture, acts as a deoxidizer, absorbing the Ozone of the air so as to form Sulphuric Acid. Sulphites are also well known when moist to behave in a similar manner. Although Sulphurous Acid, then, is a very useful artificial gaseous scavenger, it cannot compensate for the want of Nature's grand air-purifier—Ozone—of which it deprives us.

Allotropic Oxygen, the Peroxide of Hydrogen, and Nitrous Acid, are, doubtless, the three great atmospheric agents which are engaged in destroying the emanations from substances in a state of decomposition forming innocuous compounds, and in effecting other salutary changes in

[1] Chevallier: *Traité des Désinfectants.*

the maintenance of the purity of the air—a mixture of gases that is incessantly becoming contaminated by all kinds of deleterious matters, which have been included under the general term of "air-sewage." That it is extremely important to know the proportion of these oxidizing principles contained in the air of different localities must be universally acknowledged. The only test which is a faithful Ozone indicator, and the best means for estimating this body as well as the other air-purifiers, will be fully described in the following sub-section.

2. How should Ozone be observed ?

It is not sufficient to answer this question by directing those who ask it to avoid the errors that have been pointed out. It is necessary to show in what manner these fallacies may be excluded from the estimation of Ozone. The great desideratum in connection with ozonometry is a *sensitive* test, unaffected by any body except Ozone that may be present in the air, and which can be employed without any serious expenditure of time and labour. The present state of the science demonstrates that there are only two tests which merit the attention of Ozone observers—namely, the Iodized Litmus and the simple Iodide of Potassium test.

If we desire to estimate the amount of Ozone present in the air to the exclusion of all other bodies, we must employ the former test, to which alone rightly belongs the name of ozonoscope.

If we wish to ascertain the amount of those principles which purify the air, destroying putrescent emanations, and restoring salubrity to a medium which is unceasingly being polluted—such, for instance, as Ozone, Peroxide of Hydrogen, and Nitrous Acid—we may adopt the simple Iodide of Potassium test. I employ both; the Iodized Litmus being exposed without intermission, and the Iodide of Potassium being used only for hourly observations.

ON "OZONOSCOPES," THEIR MODE OF PREPARATION AND THEIR MODE OF EMPLOYMENT.

1. *On "Ozonoscopes."*

The Starch and Iodide of Potassium tests are, as has been already stated, almost universally employed in the detection and estimation of Ozone. Most unsatisfactory they all are. Some colour in lines, as, for example, Schönbein's test, the marbled appearance of which appears to be due to the layer of Iodized Starch not being of a homogeneous thickness. Lowe's tests resemble after an exposure a Scotch plaid. Others become spotted; whilst a few discolour more at one point than at another, assuming many shades of a bluish-purple hue, rendering it often impossible to assign to them a number indicative of the exact degree of coloration. Some Iodized Starch tests assume shades of different colours, instead of different shades of the same colour. Tests made according to Schönbein's formula sometimes display reddish-brown tints; whilst, at other times, an exposure renders them of a violet or bluish colour. The lightest tints of Negretti's tests are brown, and the deeper ones are violet. The tests employed and recommended by Scoutetten, when moderately coloured, exhibit, in addition to these tints, a very decided blue and black colour. Even if Schönbein's tests, which are so generally used in Germany, were trustworthy, they are not sufficiently sensitive. When exposed to the influence of atmospheres artificially ozonised to a small extent, they exhibit no coloration whatsoever. **Iodized Starch.**

Dr. Mitchell made observations at Algiers in 1855, and Dr. Scoresby-Jackson conducted an elaborate series of experiments at the same place in 1857, by means of the Iodized Starch tests. Both expressed themselves as possessing no confidence in the re-agent as an indicator of atmospheric Ozone. **Drs. Mitchell and Scoresby-Jackson at Algiers.**

Chemists think it possible, and indeed probable, that Ozone acts in some unknown manner on the Starch itself.

MM. Bérigny and Salleron.

MM. Bérigny and Salleron express their belief that complicated changes take place in the Iodide of Starch during a long exposure, and that the humidity of the air has probably much to do with these changes.

Even if we employ the purest Starch of a certain definite strength, we undoubtedly introduce a source of error, and are more likely to obtain uniform results without than with this addition. The precise action of Ozone on Iodide of Potassium is now known with exactitude, but we do not know with anything like certainty all the changes exerted by this body on a mixture of Iodide of Potassium and Starch. M. Duclaux, indeed, has very recently *denied*[1] that the *Iodide of Starch* is a *true chemical compound.* He declares that its formation is purely physical, and results from the adhesion of the molecules of its constituents. It appears that M. Personne and M. Guichard expressed the same opinion some years ago. The latter chemist, who examined the Iodide of Starch by the aid of the dialyser, writes, "The so-called Iodide of Starch is simply Starch tinted by Iodine." Watts considers that "the blue coloration is due to the formation of a loose combination of Starch and Iodine, or perhaps to the mere mechanical precipitation of the Iodine upon the Starch." The various circumstances which affect and modify the colour of the Iodide of Starch have been pointed out by Gmelin.[2]

Denial that Iodide of Starch is a true chemical compound.

The employment of Iodide of Potassium tests is attended with more difficulty than is experienced with the Iodized Starch tests, for the former being very delicate are more readily affected by the temperature and humidity of the air than the latter.

Let us profit by the mistakes of our predecessors, and prefer a tortuous path, in which we make a sure and steady progress, to a straight and short one, in which we tread with uncertainty and doubt. The results of a long series

[1] *Comptes Rendus*, February 19, 1872.
[2] *Handbook of Chemistry*, xv. 97 (German edition).

of experiments with all kinds of Ozone tests have shown me that the Iodized Litmus and the simple Iodide of Potassium tests are the only ones which can be considered trustworthy. The Iodized Litmus test measures solely the amount of Ozone present in the air, being practically uninfluenced by any other known ingredient of the atmosphere. The simple Iodide of Potassium test is not only affected by Ozone, but by Peroxide of Hydrogen and Nitrous Acid; and therefore affords an index of the sum total of those purifying principles with which Nature has furnished the air we breathe, and which are deadly foes to the volatile products of decomposing animal and vegetable matters. The Iodized Litmus test often does not exhibit any blue coloration during a period when the Iodide of Potassium and Iodized Starch tests tint strongly. The former is quite unaffected during some storms, whilst the latter are always more or less coloured by them. It is probable that the storms which do *not* affect the Iodized Litmus or true Ozone tests are accompanied by the production of Nitrous Acid, without the manifestation of a sensible amount of Ozone. The electrical discharges attending storms which *are* distinguished by a blue coloration of the Iodized Litmus tests probably resemble in their properties the condensed sparks,[1] the passage of which through the air is associated with the formation of much Ozone and a minute quantity of Nitrous Acid. These two kinds of tests act in different ways. In the case of the Iodized Litmus test, the amount of Ozone which has acted is estimated by the amount of Potash formed by the decomposition of the Iodide of Potassium and union of the Oxygen with the Potassium, whilst the quantity of Iodine liberated is disregarded. In the case of the simple Iodide of Potassium test, the amount of the oxidizing principles contained in the air is calculated from the amount of Iodine set free from the Iodide of Potassium.

Iodized Litmus.

Iodide of Potassium.

Storms characterized by a coloration of Iodide of Potassium and Iodized Starch tests and by a non-coloration of the Iodized Litmus test.

Before describing the mode in which these tests are

[1] *Vide* page 21.

prepared and employed, it is necessary to refer to the materials which should be used in their manufacture.

a. Iodide of Potassium.

In the estimation of the amount of Ozone and the other air-purifiers, it is of the first importance to make use of the purest neutral Iodide of Potassium. The mode of detecting the various impurities has been adverted to on page 184.

Purification when impure.

Houzeau recommends the saturation of the Carbonate of Potash, which is so frequently an impurity of the commercial Iodide of Potassium, with a few drops of Hydrochloric Acid diluted with about 200 times its bulk of water. The Iodine, which is always precipitated by this addition, is removed by the Bisulphide of Carbon, or by evaporating the solution to dryness with a gentle heat. Iodide of Potassium, whose alkalinity is neutralized by these means, of course contains the salt formed by the union of the acid with the free alkali. As this process, then, is in truth a substitution of one impurity for another, it is better to obtain a thoroughly pure neutral Iodide of Potassium from a manufacturer of chemicals for scientific purposes than purify an impure salt.

Chemically pure salt employed by Mr. Glaisher.

Some *chemically pure* Iodide of Potassium was prepared by Squire of Oxford Street for Mr. Glaisher some years ago, in order that this distinguished aëronaut might make some important Ozone experiments during one of his ascents. No fault can be found with the salt which is supplied to me by that well-known pharmacist, who crystallizes it several times from alcohol.

b. Paper.

Muslin, linen, and calico. German bibulous paper.

A paper consisting solely of cellulose, entirely free from all impurities, is required. In the absence of such a material, tests have been made by dipping strips of tarlatan muslin, pure linen, and calico, into the solution of chemicals. A good bibulous paper is employed by the Germans, but it contains more vegetable *débris* than can be tolerated. Dr. Day of Geelong prefers a paper known in the trade as Pirie's 19-lb. cream-wove post.

Pirie's of Aberdeen. Berzelius' filter paper.

Houzeau uses Berzelius' filter paper, called also Swedish paper, although made in France. It is very thin, and consequently exposes but a very minute quantity of the chemicals to the air. The same objection must be urged against cigarette papers which he recommends. It is wise to avoid them, for they contain Nitrate of Potash, with which they are impregnated in order to promote smouldering. The Swedish filtering paper sold in this country, of medium thickness, is, in my opinion, the best for the preparation of tests. This paper is the purest which is manufactured, containing no Starch, and being free from all reducing agents, or any substance which is calculated to interfere with the accuracy of the indications afforded by the tests. There are two kinds in the market, which are generally mingled together; one being stout and of uniform thickness, the other being thin and interspersed with spots of greater thickness. The former kind should be selected, perfectly free from creases.

Cigarette paper. Swedish bibulous paper.

2. *Mode of Preparation and Mode of Employment.*

A. Iodized Litmus Test.

Drs. Bernays and Hornidge.

Drs. Bernays and Hornidge, having like many others recognized the insufficiency of the ordinary Ozone test, were the first I believe to suggest that Ozone should be estimated by the quantity of alkali produced by its combination with the Potassium set free from the Iodide of that metal, but have never made any practical application of the excellent idea. M. Houzeau of Rouen was led to construct tests of this description by the discovery of the fact that, whilst a great number of bodies displace Iodine from Iodide of Potassium in the same manner as Ozone, Oxygen and its allotropic modification are the only ones which possess the property of forming Potash with Potassium, and that the latter, *i.e.* Ozone, solely acts thus at the ordinary temperatures. He has furnished me with the following directions for the manufacture of this test, named by him "Papier de tournesol mi-ioduré."

Preparation.

Blue Litmus is boiled in distilled water. The solution is allowed to rest for twenty-four hours, and is then decanted. The impurities, such as sand, lime, etc., contained in the Litmus having deposited themselves, we have a limpid solution which is very blue. This solution having been divided into two equal portions, one of them is reddened by the minutest quantity of Sulphuric Acid (pure). We immediately mix it with the other blue portion, to which no acid has been added, so that the alkalinity of this latter portion may saturate the excess of acid of the first portion. We thus obtain a solution of Litmus which is less blue. We divide this solution into two equal portions. We redden one by a very small amount of the same acid, and mix it in its turn with the other portion. We have thus a new solution of Litmus still less blue than the preceding. These operations are repeated until a solution of a persistent vinous red colour is obtained. The colour may be considered *stable*, when a mark made with it by means of a glass rod on a white plate does not become blue on drying. If, after desiccation, the mark is of a blue colour, more acid must be added; but if, on the contrary, the solution has assumed the colour of the skin of an onion, it is necessary to restore it to the vinous red hue by the addition of a little blue Litmus which has not been acidified. When the correct tint is obtained, we allow the solution to rest twenty-four hours, in order that Sulphate of Lime may subside, and then filter it. This solution ought to be so concentrated, that one cubic centimetre (about $\frac{1}{4}$ of a fluid drachm, or more correctly $15\frac{1}{2}$ grains) furnishes about ·012 gramme (nearly $\frac{1}{5}$ of a grain) of the dry extract at 100° C. (212° Fahr.)

A *vinous* red hue necessary.

In preparing this solution we must be careful not to confound the vinous red colour with that which resembles the skin of an onion. The existence of this latter tint indicates the addition of too large a quantity of acid, and renders the paper very slightly sensible to Ozone. The presence of a minute quantity of Sulphate of Lime in the

solution does not interfere with the properties of the ozonometric paper. Pieces of Berzelius' filter paper, having been dipped into the vinous red solution of Litmus and allowed to dry, are plunged rapidly, for a third of their length, into a solution of pure neutral Iodide of Potassium, made by dissolving one gramme ($15\frac{1}{2}$ grains) of this salt in 100 grammes (3 oz. 231 grains) of distilled water. Each piece is cut into strips of the required size.

Certain acids, even moderately diluted with water, decompose Iodide of Potassium, but, when a weak solution of this salt is mixed with extremely diluted Sulphuric Acid, no change takes place, as has been before stated. The association of an acid with the Iodide of Potassium prevents the formation of the Iodate of Potash.

Formation of the Iodate of Potash prevented.

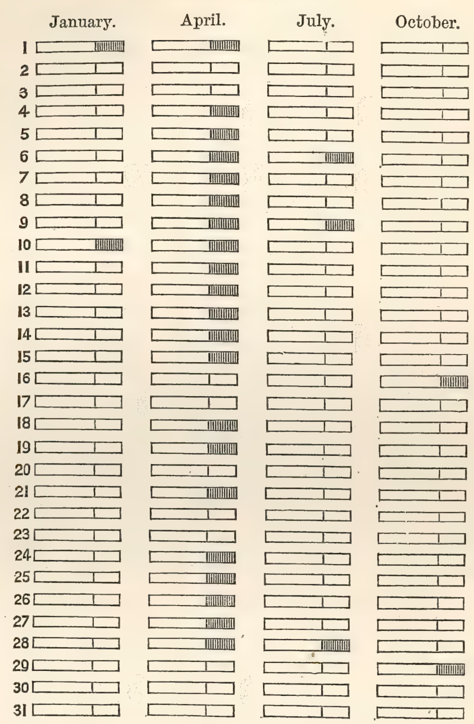
$$KI + O + SO_3\,Aq = KO\,SO_3 + I.$$

Houzeau has shown that these tests are unaffected by any Nitrogen compounds and by diluted Peroxide of Hydrogen. His statement, to the effect that very much diluted Nitric Acid, *if* it ever exists in a free state in the atmosphere, has no action on dilute neutral Iodide of Potassium, has been endorsed by Fellenburg and Rivier.

The Potash formed by the union of Ozone with Potassium turns the part of the paper prepared with the Iodide of Potassium blue, while the other part preserves its colour in contrast. This arrangement, whereby a half only of the vinous red litmus paper is impregnated with Iodide of Potassium, renders the test very convenient in chemical operations in the laboratory. Houzeau simply exposes these tests to the air for twelve or twenty-four hours beneath a plate. If the iodized part be blue, and the non-iodized part has undergone no change of tint, he concludes that Ozone has acted on the test. He does not estimate the *degree* of conversion of the vinous red into the blue colour, although he of course intimates that such may be done. He simply marks opposite each day on which the paper blues the sign ; and to every day when the paper is not blued, he attaches in the following manner :—

Employment by M. Houzeau.

TABLE 34.



Tests similarly prepared have yielded in my hands most satisfactory results. I can most thoroughly endorse the statements of M. Sylvestri of Pisa, who says that the indications of these tests are "more precise and trustworthy" than those of Schönbein.

Modifications adopted.

In making the Iodized Litmus tests I have found some difficulty in deciding as to when the vinous red tint has been arrived at. The mode of determination recommended by Houzeau has generally led me into the error of adding too much acid. A better plan is to test the solution by dipping into it strips of Swedish filtering paper and allowing them to dry.

The Berzelius filter paper has proved too thin for the manufacture of tests. It is manifestly desirable that a test should contain much more Iodide of Potassium than can possibly be decomposed by the largest quantity of Ozone ever present in the air. It accordingly becomes necessary to employ a paper stout but at the same time porous, so as to contain a certain amount of hygroscopic moisture. If a piece of such paper, coloured by vinous red Litmus, be dipped into a solution of Iodide of Potassium for a third or one half of its length, the line of junction between the iodized and the non-iodized parts is unavoidably indicated by a wavy blurred mark, which is objectionable. It will be found most convenient, in observing with this test, to be furnished with separate strips of iodized and non-iodized red Litmus paper. Pieces of Swedish filter-paper about six inches square should be wetted on both sides with the solution of red Litmus. The superfluous fluid having been removed, they are suspended in a place from which the air is excluded until they are quite dry. We iodize some of this red Litmus paper by plunging portions of it very rapidly into the solution of Potassium Iodide, and treating it in a similar manner. The squares of both kinds of paper are cut into slips of the required size. The strips should be about $\frac{3}{8}$ inch in width and $2\frac{1}{4}$ inches in length, and be preserved in well-corked bottles in a dark place. Test paper should not be touched by the fingers more than is absolutely necessary. A pair of bone or ivory pincers is very convenient. In no case should those portions of the slips which are exposed to the air ever come into contact with the skin.

Non-iodized red Litmus papers.

Size of test papers.

There is one great and insurmountable objection to this test which is the only faithful indicator of Ozone. It is not a delicate one, for unless Ozone is abundant it affords no sign of its presence.

We must not come to the conclusion that Ozone is present in air, unless we find that *the vinous red non-iodized Litmus paper has undergone no change of tint.*

Important memoranda in ozonometry.

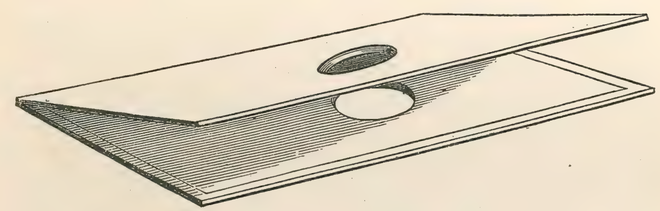
We should remember that Ozone decolorizes red as well as blue Litmus. A change of colour must be carefully distinguished, therefore, from a fading or partial removal of the vinous red hue. Nor is it to be forgotten that paper dipped in an aqueous solution of vinous red Litmus, that is to say feebly acid Litmus, becomes blue when suspended during several days in a vessel containing very moist air. This change has been attributed by Houzeau to a kind of fermentation which the colouring principles of Litmus undergo, whereby a little of the azotized matters therein contained is converted into the alkali Ammonia. As a similar transformation occurs in the solution of the vinous red Litmus also after the expiration of a week or two, even if preserved in a corked bottle, we should only make our tests with a freshly prepared liquid. If a non-iodized red Litmus test be compared after an exposure with a fresh strip, an occasional slight alteration of tint, in consequence of a very trifling fermentative change in the test itself, should not lead us into the error of supposing that it has been influenced by an alkali contained in the air. Unless we have a distinct tinge of blue in the non-iodized Litmus test, we must not decide that the simultaneous coloration of the iodized Litmus test is not due to Ozone. When testing for Ozone in laboratory work we cannot conclude, then, that it is present if the non-iodized slip is blued. In atmospheric ozonometry, conducted far away from places where Ammonia or its Carbonate is given off, the non-iodized red Litmus is rarely blued according to the experience of Houzeau, who has made more than four thousand observations in the air. The very minute amount of Ammonia which is normally contained in the atmosphere is not sufficient to colour it. The non-iodized, and even the iodized, vinous red Litmus papers indicate the fact that they have been influenced by an acid when they assume a brick-red tint, which has been compared to the colour of the skin of the onion.

Changes in non-Iodized Litmus test.

Improved mode of employment.

An iodized and a non-iodized strip of red Litmus paper are placed side by side over the mouth of the inner cylinder of the improved Smyth's Ozone box, where they are secured by an elastic band. At the expiration of twelve or twenty-four hours, during which time a constant stream of air has been passed over them by an aspirator, they are removed and *immediately* examined. They should not, like the Iodized Starch tests, be dipped in water to develop the tint. Nor should tests which have been once exposed be again employed, even if no coloration has occurred. After the removal of the tests from the Ozone box, each slip should be placed, in order that its tint may be correctly estimated, between the two leaves of a stout piece of white card-board folded on itself, and perforated with a hole about $\frac{3}{8}$ inch in diameter.

PLATE 16.



Comparison with chromatic scale No. 1.

The Iodized Litmus test should in this manner be compared with a scale, such as the chromatic scale No. 1.

B. The Iodide of Potassium test.

The employment of this test has been recommended for the estimation of Ozone by Professor Andrews, Crum Brown, and Mr. Smyth. It has been used by me for some years as an indicator of the amount of purifying agents contained in the air, but requires much care in its management.

Preparation.

The Iodide of Potassium "ozonoscopes" are most conveniently prepared in the following manner:—Swedish filter paper is cut into pieces about six inches square, which

are suspended on a line of strong thread in a dark wardrobe. The squares are dipped in a 10 per cent or 15 per cent solution of pure neutral Iodide of Potassium, care being taken to prevent each from retaining an excess of fluid, and they are allowed to dry. Each piece of paper should then have its edges removed by a pair of scissors, and be cut into strips about $2\frac{1}{4}$ inches in length and $\frac{5}{8}$ inch in width. These tests should be kept in a red *or* black stoppered bottle, which ought to be placed in a cool, dry, and dark cupboard. They should be made only at those seasons when the amount of Ozone in the air is at a minimum—when, for example, the wind is Northerly; otherwise, unless great care be taken, they are apt to assume a pale straw tint during the drying process.

Strength. Iodide of Potassium tests, constructed of 1 or $1\frac{1}{2}$ part of this salt dissolved in 10 parts of distilled water, will be perhaps found of the most suitable strength for hourly observations. A large percentage of the Iodide of Potassium does not seem to increase their sensibility. An excess of the salt stiffens the paper, which curls up and seems preternaturally dry. As has been before stated, a test should possess a certain amount of hygroscopic moisture in order to constitute an efficient one. If very strong, the Iodate of Potash cannot be estimated, as the oxidation of the Hydriodic Acid commences immediately the Tartaric Acid is applied.

Mode of employment. This extremely delicate test should be protected from moisture by four layers of the finest wire gauze. As a certain but slight diminution of colour by volatilization of the free Iodine can hardly be avoided in damp weather, when the temperature of the air is high, it is necessary to read the hygrometer at each observation. The temperature of and the amount of moisture contained in the air passing over the test being thus known, a correction can easily be made.

Formation of Iodate of Potash. The formation of the Iodate of Potash has been already pointed out as a most important source of error in

connection with past Ozone observations. The amount of Iodine set free by the decomposition of the Iodide of Potassium is the measure of the quantity of purifying agents in the air. In consequence of a portion of the liberated Iodine being often converted into the colourless Iodate of Potash, the degree of tinting becomes no longer an accurate indicator of their quantity. It becomes requisite to recover the pilfered Iodine by decomposing this salt, in order that the whole of the metalloid derived from the Iodide of Potassium may be estimated. This decomposition is effected by means of the application of an acid to the test after its exposure to the air. My attention was directed to this fallacy in ozonometry, when engaged some years since in making analyses of samples of Iodide of Potassium. It is well known that the Iodate of Potash is one of the impurities to which this salt is liable, on account of the employment of an insufficient heat in its manufacture. To detect the higher oxide Tartaric Acid is employed, which disengages both Hydriodic and Iodic Acids. These acids immediately react on each other, producing free Iodine and water. APPLICATION OF AN ACID.

Reaction.

$$5HI + IO_5 = 6I + 5HO.$$

Or, according to the new form of notation,

$$5HI + HIO_3 = 3I_2 + 3H_2O.$$

Tartaric Acid has no *immediate* effect on Iodide of Potassium, free from an Iodate, beyond the formation of Hydriodic Acid. If heated or exposed for some time to the air or to light, this Hydriodic Acid combines with Oxygen, producing water and free Iodine. When, however, the smallest trace of an Iodate is present, a discoloration *immediately* takes place proportioned to its amount. It will be observed that five parts of the Iodine of the Iodide of Potassium are deposited in conjunction with each part of the Iodine obtained from the Iodate. Here, then, in these facts familiar to most students of Materia Medica, I perceived a means of avoiding a most serious error in

ozonometry. These ideas were remarkably endorsed by the remarks of Professor Crum Brown, whose very excellent article on Ozone in the *Journal of the Scottish Meteorological Society*, January 1869, contains the following observations:—"If a mixture of Iodide of Potassium and the Iodate of Potash (in which at least $\frac{5}{6}$ths of the Iodine is contained in the former salt) be acidulated by a dilute acid, a quantity of Iodine is at once set free, exactly equal to what would have been set free by the Ozone supposing no Iodate had been formed." He does not tell us the kind of acid which should be used, or give us any instructions as to the best mode of applying it, but leaves these important points to be determined by others. Many hundreds of experiments have I made to enable me to decide

Choice of an acid.

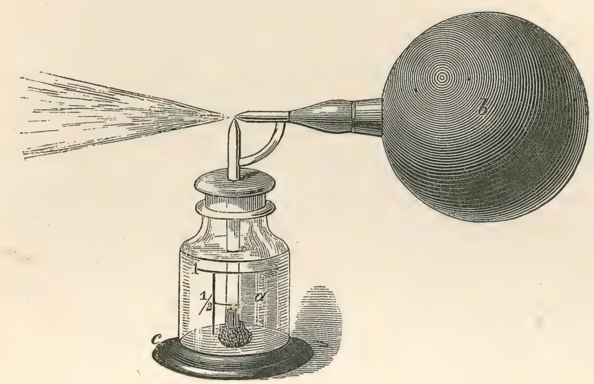
them. In the choice of an acid we must avoid any which would set free Iodine when applied to the Iodide of Potassium, and select one that simply disengages Hydriodic Acid. Hydrochloric Acid is, of course, quite inadmissible. Sulphuric Acid answers well, but must be rejected, because it so often contains, as an impurity, a little Nitrous Acid. Nitric Acid almost always contains a minute quantity of this acid, which reduces Iodide of Potassium *instanter*. Tannic, Acetic, and more than a dozen other acids have been tried in a great many different ways, with unsatisfactory results. I have arrived at the conclusion, that a solution of Tartaric Acid (ʒj to distilled water ℥j) is the best dilute acid for the decomposition of the Iodate.

Mode of applying the acid.

It may be thought that if the test paper be simply dipped, after exposure, into the solution of the acid, the increase of tint due to the decomposition of the Iodate may be conveniently noted. But it is not so, for the free Iodine is dissolved by the water. Although Iodine in its uncombined state is not very soluble in water, yet in presence of Potassium Iodide the solubility of the metalloid is much increased. The best mode of applying the dilute acid is in the form of spray. Any of the many forms of spray producers will answer the purpose, pro-

vided they emit a *fine* mist. I find the instrument here represented to be the most convenient.

PLATE 17. *Portable Spray Producer.*



a, Bottle holding a solution of Tartaric Acid.
b, India-Rubber Ball.
c, Stand weighted with lead.

A piece of sponge is attached to the extremity of the tube contained within the bottle, which filters the fluid from dust or any crystals that may form.

Comparison with chromatic scale No. 2.

Before the application of the spray it is desirable to compare the test on its removal from the Ozone box with the chromatic scale No. 2, and note the degree of coloration. When the free Iodine is in very small quantity, the water which dilutes the acid may dissolve it, and the test may thus lose the minimum amount of colour which it possessed. After this comparison, the test being firmly held by a pair of bone or ivory pincers, the dilute acid in the form of a fine mist is directed against it until it attains its maximum tint. It requires a little practice to enable one to avoid an excess, and at the same time to apply enough of the acid. If the test be uniformly *damped* on both sides by means of the spray, our object, namely the complete decomposition of the Iodate, will be attained. The test must *on no account be wetted*, for, otherwise, the free Iodine will be dissolved and cannot, of course,

in such an event, be estimated. The application of the spray of distilled water will slightly increase the colour of an exposed test, but the spray of a solution of Tartaric Acid will increase it still more if any of the Iodate of Potash be present in it. Sometimes a test after an exposure of a few hours will be found perfectly colourless, and on spraying it with Tartaric Acid it will become strongly tinted, showing the presence of an abundance of the higher oxide of Potassium. The tests should not be touched by the fingers, for the aqueous fluid with which the skin is always to a certain extent moistened contains the Chlorides of Sodium and of Potassium. Students of practical chemistry cannot fail to remember the difficulties experienced by them in keeping the borax bead free from the yellow soda flame, the slightest contact between the bead and the skin rendering experiments with other substances anything but satisfactory. Nor can the annoyances in observations with the spectroscope, occasioned by the omnipresent soda which floats in the air, be forgotten. *Directly* after the moistening by means of the spray, the test should be again compared with the chromatic scale No. 2. If an increase of colour has been effected, the number on the scale, corresponding with the degree of discoloration displayed by the test, is registered. If no increase but a diminution in tint is the result of the shower of acid, we should record the tint previously determined. If the test which has been sprayed be examined after the lapse of a few minutes, it will be found darker than it was when compared with the scale, in consequence of the commencement of oxidation.

Second comparison with same scale.

ON THE ACIDITY OF THE AIR.

It has been frequently noticed that blue Litmus paper, if exposed to the air for a longer or shorter space of time, undergoes one of two changes. It either assumes a more or less red tint, in consequence of its contact with an acid, or it becomes to a greater or less extent decolorized.

The change of colour from blue to red is due to the action of some acid, whilst the bleaching of blue Litmus is dependent on the action of the Ozone. Hence we find that the acid reaction is greater in towns than in the open country, and that the decolorization of blue Litmus follows an inverse rule. The colouring matter of red, like that of blue Litmus, is affected by Ozone, for after a long exposure it is sensibly paler than before.

Can an acid exist in a *free* state in the air?

Some have urged that it is impossible for *free* acid to exist in the air as such. There may, however, be no more alkali in the atmosphere with which it can combine. Analyses of the rainfall of cities have disclosed the fact that when Sulphuric Acid increases more rapidly than the Ammonia, the rain becomes acid.

If the presence of *free* Nitric Acid in the air is very doubtful, whilst Hydrochloric and the Sulphur Acids are the products of manufactories, towns, etc., what is the cause of the red colour which blue Litmus frequently assumes when exposed to the air of the open country? That such a change is not due to the Carbonic Acid of the air is proved by the persistence of the red colour when the red test papers are subjected to a temperature of 212° Fahr., even in a vacuum. Nitrous Acid, which is doubtless present in the air, is probably the principal cause of this change. The combustion of wood, peat, and turf, has been considered to be instrumental in the generation of Acetic Acid, which is another powerful air-purifier. Very minute quantities of Sulphuric Acid have been found at inland places far away from all human habitations. It has been supposed to originate in the open country from the decomposition of vegetable and animal matters which is generally proceeding.

Nitrous Acid.

Sulphuric Acid.

The acid reaction which blue Litmus paper sometimes exhibits during a long exposure to country air is probably due, then, to these acids, but especially to Nitrous Acid. Sulphurous Acid, which is one of the most abundant of the products of combustion, may occasionally produce this

change, as it is conveyed long distances in fogs. If a vinous red non-Iodized Litmus test acquires a brick-red tint, and a coloured Potassium Iodide paper is simultaneously bleached, the presence in the air of Sulphurous Acid may be strongly suspected. The important point for us to determine, however, is as to whether the acid or acids contained in pure air colour *true* ozonoscopes. As Houzeau's tests differ from all others in being unaffected by the many bodies present in the air, let us ascertain the result of his experiments undertaken with the object of determining this knotty question. Do the Iodized Litmus tests manifest increased coloration when blue Litmus papers assume red tints, and a diminution in their depth of colour when the acidity of the air disappears? In his pamphlet entitled "Variabilité Normale des Propriétés de l'Air Atmosphérique," he gives the following extracts from his Meteorological Journal, and the accompanying remarks on the same:—

Are true ozonoscopes coloured by the acid or acids contained in the air?

TABLE 35.

June 1860.	Air of Rouen. Higher Part—Rue Bouquet.		Air of the Country Near Rouen—Hameau des Cottes.	
	"Papier vineux mi-ioduré," indicating atmospheric Ozone. Changed every 24 hours.	Blue Litmus paper, indicating the aerial Acid. Exposed during several days.	"Papier vineux mi-ioduré," indicating atmospheric Ozone. Changed every 24 hours.	Blue Litmus paper, indicating the aerial Acid. Exposed during several days.
6	No blue coloration.	Begins to redden at the edges.	Intense blue coloration.	No acid reaction, but slight removal of colour.
	Do. Do.	Redness is manifest	Bluish - violet colour.	The same without any removal of colour.
8	Do. Do.	Redness is more pronounced.	Do. Do.	Do. Do.
14	Do. Do.	No acid reaction.	Do. Do.	Rose colour.

"We here see that the characteristic coloration of the Iodized Litmus appeared in the absence of all acid reaction, and do not observe it when the air is, on the contrary, distinctly acid." It may be said that the acidity of the air will mask the reaction of Ozone by neutralizing the Potash which it produces. Theoretically there is some foundation for the fear, but practically no opportunity has been afforded of verifying this suspected influence.

Does the acidity of the air interfere with the action of the Iodized Litmus test?

TABLE 36.

June 1860.	Air of Rouen. Higher Part—Rue Bouquet.		Air of the Country Near Rouen—Hameau des Cottes.	
	"Papier vineux mi-ioduré," indicating atmospheric Ozone. Changed every 24 hours.	Blue Litmus Paper, indicating the aerial Acid. Exposed during two days.	"Papier vineux mi-ioduré," indicating atmospheric Ozone. Changed every 24 hours.	Blue Litmus paper, indicating the aerial Acid. Exposed during two days.
16	Blue—very intense.	Decided acidity.	Bluish violet.	
17	Bluish violet.	Acidity greater.	Intense blue.	Acidity very apparent.
29	Bluish violet.	Marked indication of acidity.	Intense blue.	No observations.
30	Blue—very intense.	Acidity slightly increased.		

"Notwithstanding the persistently acid state of the air, the blue coloration of the Iodized Litmus paper has not ceased in these observations to be apparent; nevertheless, we cannot refrain from ascribing to this acid the property of diminishing the sensibility of the Iodized Litmus test."

Meteorological observations thus show that the acidity of the air, instead of blueing the Iodized Litmus tests like Ozone, tends rather to diminish this characteristic coloration when it exists.

ON ASPIRATORS, OZONE BOXES, AND THE "TUBE OZONOMETER."

1. *On Aspirators.*

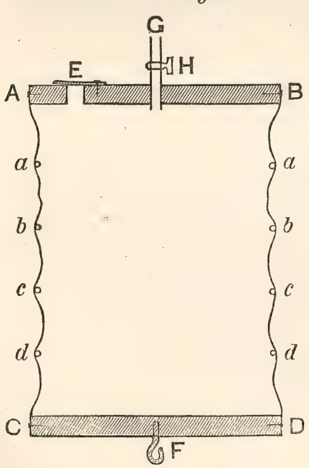
To obviate the fallacy arising from the continual

changes in the force of the wind, and the ever-varying quantities of air to which the tests are thereby exposed, it becomes essential to pass over them a known and fixed amount of air. Aspirators and Ozone boxes, the former to draw the air over the tests which are placed in the latter, are indispensable for this purpose.

In 1855 Dr. Mitchell employed a dry aspirator, similar to that which is worked in connection with Reynault's hygrometer. In 1865, Mr. Smyth made observations with a water aspirator devised by Dr. Andrews, which possesses the disadvantage of being less portable. On November 15th, 1866, Dr. Daubeny described at a meeting of the Chemical Society an apparatus which he had used for this purpose. It consisted of a glass U tube screened from the light, connected with a Johnson's aspirator, and also with an intermediate wash bottle and gas meter.

Mitchell's aspirator.

PLATE 18. *Section of Dry Aspirator used by Dr. Mitchell in Algiers.*



When the circular discs of wood AB and CD are approximated, the air in the cylinder is forced out at the valve E. A weight is then attached to hook F. The valve E immediately closes, the air entering at G, to which the Ozone box containing a test has been previously adapted. The speed at which the air passes through the box is regulated by the stopcock H. The sides of the cylinder AB and CD are made of Mackintosh cloth, and are air-tight. They are kept apart by a series of wire hoops, represented at *aa*, *bb*, *cc*, and *dd*. The upper disc AB may be fixed by a strap or other contrivance to any convenient object. A frame like a mason's horse seems to suit best.[1] Proposed

[1] *Journal of Scottish Meteorological Society*, January 1869.

dimensions—20 inches in diameter and 22 inches in depth.

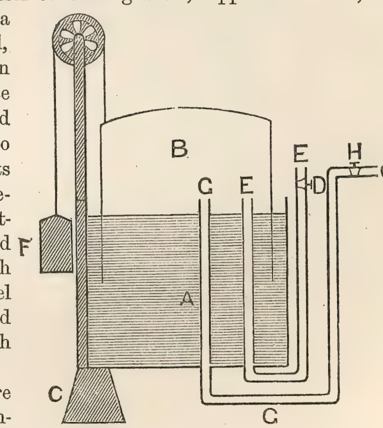
The aspirators employed in the investigations conducted by the Scottish Meteorological Society were made according to this pattern, and each of them contained about $4\frac{1}{2}$ cubic feet of air. In the construction of one of these aspirators, $18\frac{1}{2}$ inches × 45 inches, of the capacity of about seven cubic feet, I found it necessary to make each of the wooden discs AB and CD of two pieces of mahogany. Each piece was about $\frac{3}{4}$ inch in thickness. The extremities of the cylinder of Mackintosh sheeting were fixed between the edges of the pieces of wood composing each disc, by means of a solution of india-rubber. These pieces were then firmly screwed together along the whole of their circumference, about $\frac{1}{2}$ inch from their margins. The brass or galvanized iron wire hoops were maintained in their position by strips of Mackintosh cloth, which were fixed to the interior of the cylinder by india-rubber solution. The diameter of the tube G should be the same as that of the tube of the Ozone box, namely $\frac{1}{4}$ inch.

PLATE 19. *Section of Water Aspirator devised by Dr. Andrews*[1] *and employed by Mr. Smyth.*

Andrews' aspirator.

A is a large cylindrical vessel containing water, supported on feet, one of which is shown at C. B, a smaller cylindrical vessel, placed in an inverted position in A, and suspended by three cords passing over pulleys, and having weights attached to them (one of these, with its pulley and weight F, is represented in the figure); the bottom of the vessel A is pierced by two tubes E and G, which open internally above the level of the water, and are provided at their external openings with stop-cocks D and H.

The weights are made more than sufficiently heavy to coun-



[1] Described by Dr. Andrews in the *Philosophical Magazine*, November 1852.

terbalance the vessel B, so that when the stop-cock H is opened, air rushes along the tube G, and B rises. When B is full of air, H is shut, and D opened, and B pushed down; the air then escapes by the tube E, and the action may be repeated. The Ozone box is attached at HG.

The air is perhaps more conveniently discharged by allowing a large annular weight suspended above the instrument to descend and rest upon its top until the vessel B is empty. The discharge stop-cock D is then closed, the circular weight is pulled up, and the lateral weights which elevate the cylinder are slung on.

Mr. Smyth has worked with aspirators of this pattern of different capacities—namely 110, 83, and 22 gallon instruments. They are rather costly and, by reason of their size, extremely inconvenient.

In these experiments Mr. Smyth passed about three gallons of air per minute over his tests. He suggests that every observer should operate daily on twenty-two gallons of air, to which quantity a test might be exposed in about five minutes.

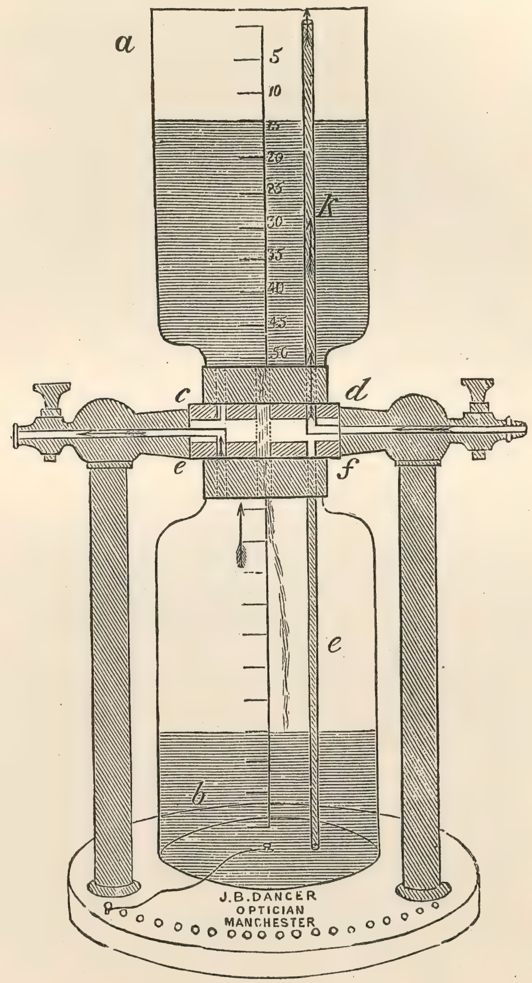
This form of aspirator was furnished, as originally devised by Dr. Andrews, with a clock-work arrangement, so that the rate at which B ascends could be regulated. The addition of this piece of mechanism is of course attended with a considerable increase in the price.

Objections to foregoing aspirators.

Both of the aspirators which have been described are open to two serious objections. The velocity of the entering air is always changing. At the commencement of an observation, when there is an incomplete vacuum, the air enters with a velocity greater than towards the termination of the same, when the velocity is at its minimum and the equilibrium is nearly restored. In the common bottle aspirators, where the weight of the column of water furnishes the motive power, the same source of error exists, the velocity of the air being greater when the bottle is nearly full than when it is nearly empty. One of the most convenient and ingenious aspirators constructed on the ever-changing-velocity principle is represented in

Dancer's reversing aspirator.

PLATE 20. *Dancer's Reversing or Swivel Aspirator.*



Two glass jars, graduated into parts of a cubic foot, or according to pleasure, are fixed mouth to mouth on an axis, *c, d, e, f,* the shaded part of which revolves with them. When the upper jar is filled with water and the taps are opened, the water flows from *a* to *b*, the air entering the jar *a*

through one of the stop-cocks, which is connected with an Ozone box by an india-rubber tube. As *b* fills, the air contained in it passes out by *e* through the other tap. When *a* is empty, it is simply turned around by the hand, and *b*, the filled jar, stands uppermost. A second charge of air may then be transmitted over the test. The number of charges is registered by placing an ivory peg in holes at the foot of the instrument. The necessity of occasionally reversing the jars is a great objection to this aspirator. It can only be removed by employing very large metal cylinders provided with glass graduated gauges.

In the estimation of the air-purifiers, it will not suffice to ascertain the amount present in the atmosphere during five minutes only of every twenty-four hours. We want to know the maximum that has occurred during that space of time. It becomes necessary, then, either to make several observations every day, by means of a machine of twenty-two gallons, or obtain a gigantic and cumbrous aspirator which will work for twenty-four hours. The manipulation of Mitchell's aspirators is somewhat laborious work. Few, moreover, have time to make several observations daily

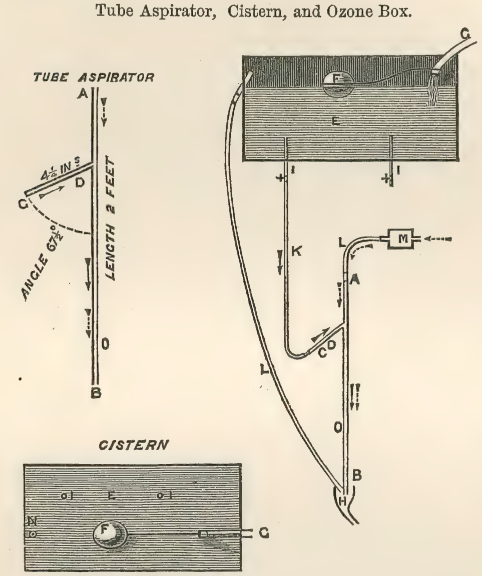
Kind of instrument required.

An aspirator is wanted of small size, requiring but little water, of simple construction, easily worked, inexpensive, and which passes a stream of air of minimum velocity.

Tube aspirator.

PLATE 21. *Section of Water Aspirator which is employed by me in the estimation of Ozone and the other air-purifiers.*

Tube Aspirator, Cistern, and Ozone Box.



AB, Gas Tube, $\frac{1}{4}$ inch in diameter.
CD, Gas Tube, $\frac{3}{16}$,, ,, ,,
E, Small Cistern.
F, Ball Tap.
G, Supply Water Pipe.
H, Discharge ,, ,,
II, Gas Tubes, $\frac{3}{16}$ inch in diameter, inserted into bottom of cistern, and provided with small stopcocks.
K, India-rubber Tube, $\frac{1}{8}$ inch in diameter.
LL, ,, ,, $\frac{1}{4}$,,
M, Ozone Box.
N, Safety Pipe to prevent inundation in case of formation of ice in cistern, and its interference with action of ball tap.
O, Exit portion of Tube Aspirator.
——> Indicates direction of current of water.
····> Indicates direction of current of air.

Both the tube aspirator and the cistern can be made by any plumber for a few shillings.

The tube aspirator consists simply of two tubes,

Description of tube aspirator.

differing from one another in diameter and length, which are connected together at a certain angle. The longer tube is about 2 feet in length and $\frac{1}{4}$ inch in diameter, whilst the other is $4\frac{1}{4}$ inches long and $\frac{3}{16}$ inch in diameter. The short tube is fixed to the long one at 4 inches from its upper extremity, so as to form an angle of about $67\frac{1}{2}°$ with the exit portion or the lower extremity of the latter (O). If a more rapid current of air be required, the longer tube should be $\frac{1}{32}$ inch less in diameter, whilst the short tube must be connected with it at a more acute angle (about 55°). As the pressure of the water in the supply pipe is continually varying, it is necessary to connect the tube aspirator with a cistern provided with a ball-tap, which maintains the water always at the same level. If it is not convenient to employ the cistern supplying the closet for this purpose, a little reservoir of water, $16\frac{1}{2}$ by 10 inches in length and breadth and 8 inches in depth, can very easily be made by lining any strong box of the above internal dimensions with sheet lead, and fixing to the supply-pipe a ball-tap. To prevent any interference with the continuance of observations during the extreme cold of winter, the cistern should be within the house.

The water passing from the cistern E through the small india-rubber tube K runs through CD into AB, making its exit at B. In so doing it creates a partial vacuum along the tube AL, to supply which air rushes in an intermittent manner through the Ozone box M. The tubes II are carried for some little distance above the floor of the cistern, to prevent their obstruction by any foreign matter which the water might contain, or by any salts which might be deposited from it. The second tube I is designed for the attachment of another tube aspirator.

If the column of water, measured from its surface in the cistern to C, be about 4 feet in height, between 3000 and 4000 cubic inches of air per hour will be transmitted

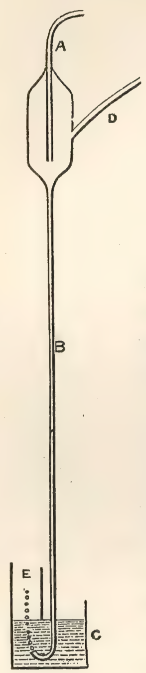
through one of these aspirators. This current, which is the slowest that can be conveniently obtained, equals about a mile per hour, and possesses a pressure of about ·01 of a pound per square foot. The exact number of cubic inches may easily be found by attaching a small gas meter, such as is employed in chemical operations, to the aspirator. In the absence of one of these instruments, the amount of air which is transmitted may be estimated with sufficient accuracy by inverting a jar or other vessel, holding exactly a gallon of water, into a trough containing water, and by allowing the air passing out at B to gradually rise into the vessel and displace the water. To facilitate this operation the lower extremity of the tube aspirator (B) should be tightly inserted into a curved piece of lead pipe about 3 or 4 inches long, which permits the air to pass underneath the lip of the vessel. The number of minutes and seconds occupied in the removal must be noted with precision. Knowing the time required by a gallon (277·274 cubic inches) of air to displace a gallon of water, it becomes a very simple matter to calculate the quantity of air which would pass out of the aspirator in an hour. To convert the cubic inches into linear inches, it is only necessary to divide them by the *area* of the tube through which the air enters the aspirator.

Measurement of quantity of air transmitted.

A proposal has reached me from Mr. Dewar of Edinburgh to employ a water aspirator of the following construction, which bears a great resemblance to mine.

Dewar's modification of tube aspirator.

PLATE 22. *Dewar's proposed Water Aspirator.*



A, Water supply pipe.
B, Gas pipe ¼ inch in diameter of any length up to 30 feet.
C, Vessel for waste water, and for the measurement of the air drawn through the tube.
D, Pipe to be united with the Ozone box by means of an india-rubber tube.
E, Part of vessel where the air is measured.

Compara-tive experi-ments with tube as-pirator, and Dewar's modifica-tion of the same.

Several tube aspirators with this dilatation at the upper extremity have been compared by me with others without the expansion. The most efficient one which I manufactured was rapidly made with an india-rubber ball, provided at each end with a tube of the same material, such as is sold with spray producers. A long piece of gas-pipe, $\frac{1}{4}$ inch in diameter, was slipped into its exit tube, and a black rubber tube of the same size for the entrance of air was attached by means of a solution of caoutchouc to its upper part, about $1\frac{1}{2}$ inch from the supply pipe. The non-provision for the maintenance of a current of unvarying velocity, and for the constant flow of the same amount of air per hour over the test, is a great fault in this instrument. The pressure of the water in the pipes of our towns presents great differences, and changes frequently in the same pipes, being governed by the consumption and other causes.

In my experiments I have found that it is easy to obtain a current of air of great velocity with Dewar's aspirator, but almost impossible to procure a *continuous* current of *little velocity.* If the force of water in the supply-pipe is diminished, an intermittent stream of air is produced. This difficulty is not experienced if the very simple aspirator, which has been recently suggested by Herr C. Christiansen in Poggendorff's Annalen, be adopted.

Christian-sen's form of tube aspirator.

He attaches a bit of thick, large, caoutchouc tube to a water-supply pipe. The side of the tube is pierced with a red-hot needle, and the curved extremity of a piece of small glass tubing is introduced through the aperture. The open ends of the glass and water-supply pipes are of course directed towards the exit portion of the india-rubber tube. If the sides of the last named are slightly approximated at a point between its exit and the glass tube, the power of the instrument is much increased, and an almost complete vacuum is formed. This aspirator, although exceedingly useful in brief experiments, is unadapted for continuous ozonometrical observations, in consequence of the large amount of water which it requires. The objections to a current of great velocity, and the necessity for employing one of minimum speed, are elsewhere pointed out. The inability to pass a *continuous* current of air of *minimum* and *unvarying* velocity over tests by means of a *small amount* of water has induced me to prefer an aspirator which can *only* transmit an intermittent stream of air, such as is depicted in Plate 21. As chemical action requires time, a longer period is also afforded by the interrupted current for the air to exert its full influence on the test paper than if it were a continuous one.

The Position of the Aspirator

employed is of some moment. There is no occasion to refer to the necessity of fixing this instrument in a place free from all organic decomposing matters, for the importance of such a precaution must be patent to all. Observations should be conducted in situations far away from all dung-heaps, privies, sinks, drains, or other sources of noxious gases.

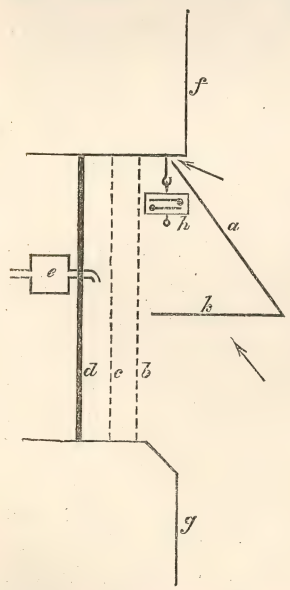
It seems desirable, in order to avoid any chance of encountering Nitrites, to operate on a stratum of air not higher than about four feet from the earth, taking care to protect our tests from any emanations proceeding therefrom. Both Nitrates and Nitrites are formed in the moist portions of certain soils, and are raised to the sur-

face by capillary attraction. The soils in which they are produced contain a great excess of animal *débris,* mingled with much Carbonate of Potash, Lime, or some other basic substance which can combine with the Nitric or Nitrous Acids set free at the moment of their generation. Ammonia is often oxidized during the progress of putrefactive changes in animal matters on the surface of the earth. How important is it then to be exceedingly cautious in the choice of a site if we would obtain truthful results!

Suggested arrangement.

The air experimented upon should be screened from the sun's rays by a wooden shade, covered with tar felt, and furnished with sides. It may then be advantageously transmitted through two sheets of finely-perforated zinc, separated from one another by an interval, before it passes through the Ozone box. We by these means examine air which preserves its natural temperature and hygrometric condition, and which is comparatively free from dust.

PLATE 23.



a, Shade of wood covered with tar felt.
b c, Layers of perforated zinc.
d, Window of wood, with one or two holes for insertion of Ozone box or boxes.
e, Ozone box.
f g, Wall.
h, A verified Mason's hygrometer suspended on a hook.
k, The side of wooden shade remote from spectator.

The foregoing sketch accurately represents the

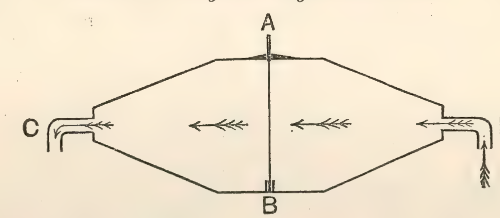
arrangement which has been adopted by me. A Northerly aspect is undoubtedly preferable for ozonometry, as also for the majority of meteorological observations.

2. *On Ozone Boxes.*

A test paper placed in the tube of an aspirator through which air passes is tinted, but not in a uniform and satisfactory manner. It is needful to have an extended surface of the test exposed in a dark box to obtain comparative results. Several forms of Ozone boxes have been made differing but little from one another. The box invented by Mr. Smyth is, with one or two additions and alterations, undoubtedly the best.

PLATE 24. *Section of Ozone Box made for Dr. Mitchell in 1855 by an Algerian Arab.*

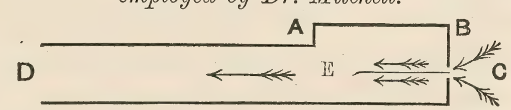
Dr. Mitchell's No. 1.



"It was made of tinned iron, and was about 5 inches long, 2 inches deep, and 1 inch broad. It was fastened on the top of a post, in the open air, at B. AB is a sliding diaphragm, which can be pulled upwards in the direction of A, and in an aperture in this diaphragm the paper is fixed. It is connected with the aspirator at C by means of a flexible tube. The air drawn through the box enters by the tube at D, and passes over the paper before making its exit at C. The bent form of the tube at D excludes light."—*Vide Ed. Phil. Jour.*, July 1860.

PLATE 25. *Section of another form of Ozone Box employed by Dr. Mitchell.*

Dr. Mitchell's No. 2.



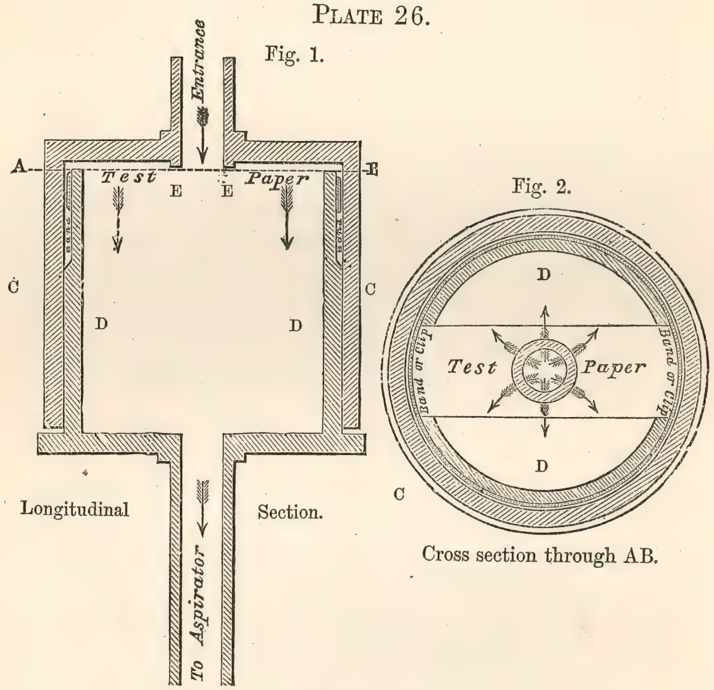
AB, Lid which opens and permits of the change of tests.
C, Aperture through which the air enters.
D, Exit tube to which aspirator is attached.
E, Test placed across the tube.

It will be observed that the air impinges on the surface of the test in the box (Plate 24), whilst in this box it strikes the edge of the paper, passing above and below it in its progress towards the exit tube.

The Ozone box described by Mr. Smyth at the meeting of the British Association in 1865 is far superior to either of those which have been sketched.

Mr. Smyth's.

PLATE 26.



Figs. 1 and 2.

AB, Test paper. DD, Inner cylinder.
CC, Outer cylinder. EE, Projecting portions of entrance tube.

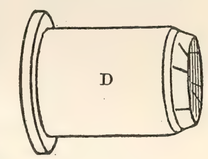
Here are his words:—"Two inside-coated brass, hard wood, or opaque glass tubes or boxes are made about 2 inches long and 2 inches in external diameter. The inner one is so much less than the outer as to screw or fit tightly into it; it is also about $\frac{1}{8}$ of an inch shorter, and

its extremity at the point of the screw is grooved for an india-rubber band, which holds the test stretched across its mouth." The entrance and exit tubes are $\frac{1}{4}$ inch in diameter.

The inner cylinder of this box (Plate 27) was originally made with slits cut at its open extremity, in order to set the tests at various angles to the current of air. It was soon found, however, that, *unless the paper be placed at right angles to the inflowing air, the test does not receive its full influence.* The Ozone box employed by the Edinburgh investigators, and the modification of it recommended by Mr. Dewar, which are represented below, are both constructed so that the air shall strike the edge of the test instead of its surface.

PLATE 27.

Perspective View of the Inner Cylinder (diminished in size).

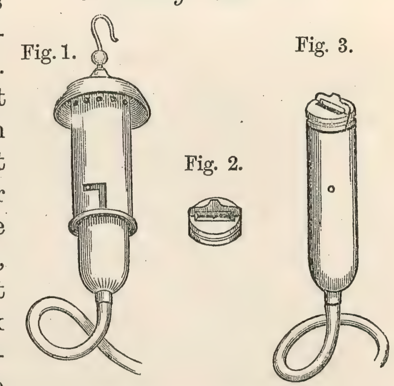


Box used in Edinburgh.

This box (Fig. 1, Plate 28) is made of well-seasoned boxwood. Its separate parts are represented in Figs. 2 and 3. Fig. 2 shows the top part of the wooden box, with the slit and the support by which the test paper is held stretched in the central plane of the slit, so that all the air that enters the wooden box passes as a thin flat current on each side of the test paper. Fig. 3 displays the wooden box with the top attached to its upper part and a gutta-percha tube to its lower. Fig. 1 shows the wooden box with its outer casing, which is pierced with small holes for the admission of air to the test papers. By this arrangement

PLATE 28.

Edinburgh Ozone Box.



the test papers are protected from the effects of light. The gutta-percha tube seen at the lower end of Fig. 1 is attached to the aspirator.

Mr. Dewar's modification of the above is made entirely of glass, and is similarly connected with an aspirator.

Mr. Dewar's glass box.

PLATE 29. *Mr. Dewar's Glass Ozone Box.*

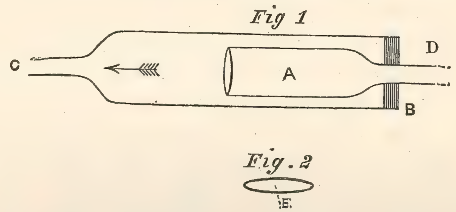


Fig. 1. A contains the test paper supported on a piece of platinum wire gauze, so that both sides of it may be exposed to the current of air.
B, A ground glass stopper which can be removed and replaced when requisite.
C, Exit tube.
D, Entrance tube.
Fig. 2. E, Transverse section of A.

The very excellent little Ozone box of Mr. Smyth (Plate 26) is open to two or three serious objections :—

1. The test is not in darkness.

2. The test sometimes becomes very damp in wet weather. When we employ the simple Iodide of Potassium test, the free Iodine is under these circumstances volatilized.

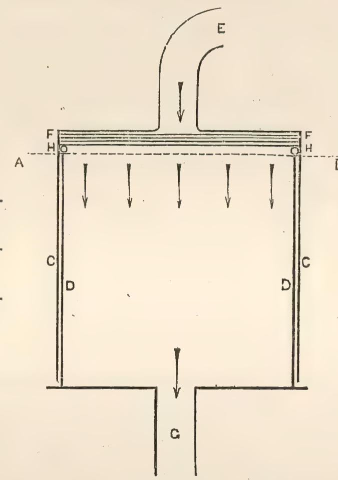
3. The air, by reason of the projections EE, being directed against the centre of the test, a small circumscribed spot only becomes tinted. If these projections are removed, that portion of the test immediately opposite the entrance tube is disposed to assume a darker hue than the extremities of the slip.

Improved Smyth's box.

The improvements which I have made in the box consist simply in curving the entrance tube, and in interposing, between its inner opening and the test paper, layers of platinum gauze to exclude light, moisture, dust,

particles of soot, etc. The four circular pieces of very fine platinum or brass gauze (70 to the inch) also diffuse the air over the paper. All spotting is thus avoided, the test being uniformly tinted throughout its length.

PLATE 30. *Improved Smyth's Ozone Box.*



AB, Test Paper.
CC, Outer Cylinder.
DD, Inner Cylinder.
E, Curved Entrance tube.
FF, Layers of fine wire gauze.
G, Exit tube.
HH, Galvanized iron wire ring.
The entrance and exit tubes are ¼ inch in internal diameter.

If brass gauze be used, each piece should be painted over with a little thin japan varnish, guarding at the same time against the accidental occlusion of any of the holes. I have elsewhere referred to the frequent presence of minute quantities of Ammonia in the air, as a product of the decomposition of organic matters, and have shown that it has no effect on "ozonoscopes" except in a concentrated state. If air, containing a very minute quantity of Ammonia, be passed over Copper or Brass (by reason of the Copper therein contained), oxidation of the Ammonia results, in consequence of a catalytic action exerted by the Copper, and Nitrous Acid is produced which colours the simple Iodide of Potassium tests. If the surface of the brass gauze be covered with a varnish no change occurs. These layers of fine gauze do not in any way

interfere with the ingress of air; whilst, with the assistance of the curve in the entrance tube, they practically exclude all light.

I have frequently observed, during a fog, coloured Iodide of Potassium and Iodized Starch tests, suspended in Clarke's cages and louvre boxes, become completely blanched; whilst tests precisely similar were unaffected in my Ozone boxes, protected in this manner with layers of gauze.

As moisture does not injuriously influence, and a small amount of light does not interfere with, Iodized and non-Iodized Litmus tests, it is only necessary to insert within the box devoted to these papers a couple of circles to diffuse the air over them and prove a defence against dust.

Connections of Improved Ozone Box with the Aspirator and the External Air.

The Ozone box should communicate with the aspirator by means of a piece of new black caoutchouc tubing $\frac{1}{4}$ inch in diameter, and about two or three feet in length.

Vulcanized rubber tubes should be avoided.

The white and brown vulcanized india-rubber tubes contain much Sulphur, an element which forms with Oxygen and Hydrogen compounds much to be dreaded in ozonometry. It has been found that, if air be passed through a vulcanized tube before it is brought into contact with a Potassium Iodide or Iodized Starch test, the paper remains uncoloured. The inner surface of the tube is coated with Sulphur, which is oxidized as the air rushes over it. The Sulphurous Acid thus derived bleaches the Potassium Iodide or Iodide of Starch tests as rapidly as they become coloured. It is not sufficient to avoid the employment of vulcanized tubes as conductors between Ozone boxes and aspirators, and, *à fortiori*, the passage of air through them before it reaches the test papers, but it becomes needful that air should not be transmitted through long pipes of any description before arriving at "ozonoscopes."

Observation of Prof. Palmieri of Naples.

Professor Palmieri of the Observatory of Vesuvius, in his endeavours to ascertain whether any relation exists between the electrical tension of the air and the depth of coloration of the Iodized Starch test, discovered[1] that "the passage of air through a tube of glass was attended by the removal, to a very great extent, from it of the property of colouring ozonoscopic papers." M. Houzeau had previously noticed this fact, and accounted for it by supposing that the Ozone partly destroys itself, in consequence of the friction it undergoes against the walls of the tube. This explanation is extremely unsatisfactory. The following experiments, performed by me in July 1872, confirm the observation of Palmieri:—Two tube aspirators, which pumped air at different velocities, were brought into requisition, (*a*) passing 4000 cubic inches, and (*b*) 6000 cubic inches per hour. The air, in order to reach the test paper in the Ozone box connected with (*a*), was sent through a glass tube only $1\frac{3}{4}$ inch in length; whilst in the case of (*b*) it was compelled to traverse a tube 10 feet long of the same material and internal diameter. When the Ozone in the atmosphere was abundant, the aspirators were made to draw air for many hours through these tubes over 15 per cent Potassium Iodide, Iodized Starch, and Iodized Litmus tests. The friction and consequent retardation of the current of air necessarily produced by its passage through the long tube with its several bends was compensated for by the greater velocity with which the aspirator (*b*) transmitted it. In all the experiments, the tinting of the test connected with the long tube was less than that attached to the short one, although the coloration of the latter was always decided and unmistakable. On filtering the air through cotton wool before permitting it to enter the long tube, so as to intercept bodies which would otherwise have been spread out over this extended tubular surface, I noticed but little difference in the degree of coloration of the "ozonoscopes"

Experiments.

[1] *Compt. Rend.*, May 6, 1872.

in communication with the long and short pipes. It is extremely probable that the solid impurities contained in the air are deposited on the sides of the long tube, and that the Ozone in its passage over them is partly consumed in oxidizing the same. That the particles contained in the atmosphere are thus retained was shown by Pasteur, who found that air, filtered of active agents by its transmission through long tubes, lost the power of exciting decomposition. Dr. Angus Smith has noticed that a large portion of the salts and acids contained in impure air is collected on the sides of a long tube through which this medium may be drawn. He writes,[1] "The matter seemed to be lost. It took me long to believe that the side of the tube could be so efficient."

Pasteur.

Dr. A. Smith.

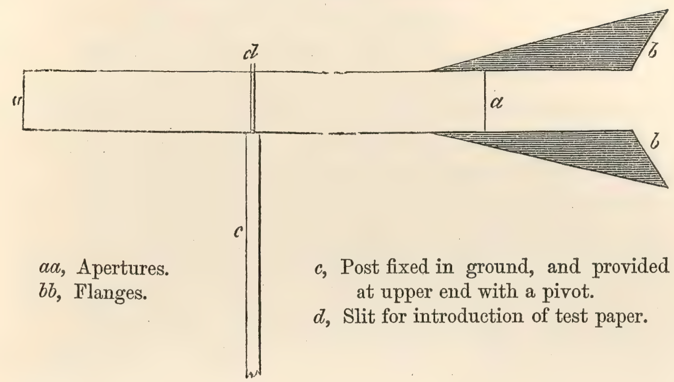
The entrance tubes of Ozone boxes should not exceed two or three inches in length, and should be in direct communication with the external air.

3. *The "Tube Ozonometer."*

With the intention of removing the error arising from the frequent variation in the quantity of air passing over "ozonoscopes," Dr. Moffat has recently devised an instrument called by him a "tube ozonometer," in connection with which an anemometer is employed. It consists of a tube, four inches square and four feet in length, which is made to turn upon a pivot that rests on a post, about four feet high, inserted in the ground. One extremity of the tube is furnished with flanges, which permit of its rotation by the wind. The aperture, in consequence of this arrangement, always points to the direction from which the wind blows. A clip holding a test paper is introduced into the tube through a slit in its upper surface.

[1] "Fifth Report under the Alkali Act, for 1868."

PLATE 31. "*Tube Ozonometer.*"



aa, Apertures.
bb, Flanges.

c, Post fixed in ground, and provided at upper end with a pivot.
d, Slit for introduction of test paper.

At night and in the morning, when the tests are changed, the velocity of the wind passing through the tube is ascertained by holding a Biram's 4½-inch anemometer to the aperture at which the wind enters.

Employed in conjunction with an anemometer.

Dr. Moffat has made a comparison[1] between the results yielded by a 30-gallon aspirator of Dr. Andrews' pattern (Plate 19, page 251) and by his "Tube Ozonometer."

Comparison of observations made with Andrews' Aspirator and Moffat's "Tube Ozonometer."

TABLE 37.

The DEPTH of TEST COLORATION indicated by Dr. Moffat's IODIZED STARCH PAPERS, exposed to 300 gallons of air from each point of the Compass in an Andrews' ASPIRATOR and the "TUBE OZONOMETER."

Quantity 300 Gallons.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Total.
Tube Ozonometer	1·7	0·3	0·1	2·3	2·1	6·5	2·5	1·5	2·1
	N. Points, 1·1.				S. Points, 3·2.				
Andrews' Aspirator	0·0	0·0	0·0	2·2	3·3	3·8	1·3	1·1	1·4
	N. Points, 0·5.				S. Points, 1·2.				

[1] "On the Tube Ozonometer." Paper read at the meeting of the Brit. Assoc. Adv. Science, 1872.

Result.

The tests exposed in the "tube ozonometer" would seem to have exhibited deeper tints than those connected with the aspirator. He writes, "Whilst every particle of air which enters the aspirator comes in contact with the test, not $\frac{1}{4}$th part of that which passes through the 'tube ozonometer' impinges upon the paper in the tube." Dr. Moffat considers that the observations made with the aspirator are unsatisfactory, and that the necessity which exists for refilling it with water so many times a day renders the employment of such an instrument by a man of business extremely inconvenient.

As the force of the wind is continually changing, an observation with an anemometer twice or even thrice a day cannot but give inexact results. In order to obtain reliable observations with the "tube ozonometer," the quantity of air passing over a test paper during every hour of both day and night should be known. An anemometer which would furnish an uninterrupted record of the velocity of the wind, or one which would at least indicate its maximum velocity during every twelve hours, appears indispensable as a constant companion of this instrument.

Possibility of the existence of a larger amount of Ozone during windy than calm weather.

It is quite possible that, even when employing aspirators or other contrivances by which we pass over the tests air whose amount and velocity does not vary, we may ultimately discover a larger amount of Ozone in the atmosphere during windy than in calm weather. (*Vide* pages 123-124.) It has been considered probable that positive and negative electricity are developed by the friction together of two currents of air charged to different degrees with moisture. We know that electricity may be generated not only by the friction of condensed particles of water, as in the hydro-electric machine, but by that of jets of condensed air under a high pressure.

THE INFLUENCE OF THE HYGROMETRIC CONDITION OF THE AIR ON "OZONOSCOPES."

Moisture, like warmth, favours chemical action, whilst a dry and cold medium retards it.

The influence of the thermometrical and hygrometrical states of the air on the Iodized Starch tests has led some to ascribe the differences in the depth of their coloration solely to the effects of this chemical law. Indeed, Dr. Stark, in an address delivered in January 1858 before the Meteorological Society of Scotland, expressed a doubt whether "ozonoscopes" indicated anything more than the quantity of moisture in the air. We must remember, however (1), that the development of Ozone and other atmospheric purifying agents is regulated by the same conditions of temperature and humidity; and (2), that other "ozonoscopes" of different chemical construction, which are not so susceptible as the Iodized Starch test to the influence of moisture, agree with the latter in the variations of tint which it displays.

Regarded as hygrometers.

The presence of a certain amount of moisture in the air appears to be indispensable for the detection of Ozone. Highly ozoniferous air passed through U tubes containing at one time Chloride of Calcium, at another Quicklime, and at another Caustic Potash, communicated no colour to 15 per cent Iodide of Potassium tests. Dr. Andrews, who has made so many important discoveries respecting Ozone, recently communicated to me his belief that an Iodide of Potassium "ozonoscope" should, in order to prove an efficient test, contain a certain amount of hygroscopic moisture, and ought therefore to be made of bibulous paper.

Certain amount of moisture indispensable for detection of Ozone.

Houzeau states that dry Ozone has no action on Iodized Starch tests, that Ozone very feebly moist produces a slight colour, and that Ozone containing much moisture rapidly communicates to them the deepest tint which they

can assume. The amount of Ozone in each experiment which he performed was of course the same.

Blanching from excess of humidity in air frequently occurs.

Although in atmospheric "ozonometry" test papers should not be devoid of humidity, they should not be damp. When air contains an excess of moisture, a decrease of colour, and sometimes a complete blanching of the coloured tests, is frequently observed. How is this effect produced? Why is it not always the result of the contact of excessively humid air with the tests?

How does an Excess of Moisture in the Air produce a removal of Colour from a Coloured Test?

a. Coloured Iodide of Potassium Test.

The colour disappears in consequence of the volatilization of the free Iodine, the metalloid being prone to escape when in a moist condition, especially when the temperature is high.

b. Coloured Iodized Starch Test.

Some tests blanch more readily than others.

These tests are not injuriously affected to such an extent as the Iodide of Potassium tests by a large amount of moisture. They differ very much in their degree of susceptibility to the influence of the hygrometric condition of the air according to their mode of preparation—*e.g.* Schönbein's tests lose their colour much more readily than Negretti's. Although the blue Iodide of Starch is very sparingly soluble in water, this solubility is increased if the Iodide of Potassium employed in the manufacture of tests be alkaline. Carbonate of Potash, the impurity which gives it alkalinity, being a deliquescent salt, tends to maintain the tests in a moist condition.

Experiments relative to vaporization of the Iodide of Starch.

If the Iodide of Starch be so slightly soluble in water, how does it happen that these tests often and rapidly become, when they are wet, completely blanched? If a deeply tinted Negretti's test be cut into small portions and placed in a little distilled water, some difficulty will

be experienced in rendering the fragments colourless. Many hours, and perhaps a day or two, will elapse before all colour is removed from them. If, on the other hand, a coloured Negretti's test be kept in a moist condition with distilled water, conducted to it by a fine thread of lamp wick or darning cotton, the colour will rapidly disappear. In the latter experiment the Iodide of Starch becomes vaporized with the water which is unceasingly being evaporated from the test. Again, if we add to a solution of Iodide of Potassium a minute quantity of Iodine, and then a little cold solution of Starch (thus forming a mixture such as is found in an Iodized Starch test which has been coloured by an exposure to the air), the blue Iodide of Starch will of course be precipitated, and may be caught by passing the mixture through a fine filter. Let this filter paper, coated as it will be with a great deal of the Iodide of Starch, be spread out on a plate and maintained in a moist condition by means of a lamp wick connected with a little bottle of water: It will be found that all this Iodide of Starch will gradually disappear, and the filter paper will be left colourless. These experiments should be carried on in a room closely protected from the entrance of the outer air, either through the door, chimney, or window.

Reddish-brown hue sometimes assumed by Iodized Starch tests.

The violet tint of the coloured Iodized Starch test is sometimes replaced by a reddish-brown hue. This change is often noticed on one side only, and shows that moisture has come into contact with the test paper. The Iodide of Potassium contained in the "ozonoscope," when dissolved by the addition of a little water, acts on the Iodide of Starch in some unknown way, producing this alteration in colour.

Why is not Blanching of Coloured Ozonoscopes always the result of the contact of excessively Humid Air with them?

Observers have remarked that coloured "ozonoscopes"

sometimes lose their colour, whilst at others they preserve it, during wet weather.

a. Coloured Iodide of Potassium Tests

Reasons.

are sometimes found quite wet, yet no blanching takes place. This is observed occasionally when a steady downpour of rain is accompanied by a *low* temperature and a complete calm. If there is much rain the superficial layer of free Iodine is alone removed, in consequence of its solution by the moisture, whilst the great bulk of the free Iodine more deeply situated in the test is uninfluenced. I have noticed this non-blanching of Iodide of Potassium tests when cold North-westerly rains have descended and no wind has agitated them. It is also observed when cold North-easterly highly ozoniferous sea-winds, attended by continual heavy showers, are present. If a wind which is not strongly ozoniferous arises, or if the temperature increases, the wet tests soon lose their colour. The explanation of these facts is simply that when the colour tests are subjected to incessant additions of moisture, which are brought to them by a very damp current of air containing no Ozone, or but a small amount, the ever increasing quantity of the solvent soon dissolves all the free Iodine which the test contains. If the wind is highly ozoniferous, the loss is to a certain extent compensated for by fresh decompositions and liberations of Iodine. Although Iodine is very slightly soluble in water, it is freely dissolved in this medium when conjoined with Iodide of Potassium, as it is in this test.

Iodine is particularly liable to volatilize when in a moist condition on any sudden increase in the temperature. Hence we find that blanching is more likely to occur when the air is warm and moist than when it is cold and moist.

b. Coloured Iodized Starch Tests.

Blanching of these tests when properly protected does not generally take place, if the Iodide of Potassium of which they are made be neutral, unless the moisture settles on the test, as in the case of fogs. They lose their

colour more readily during wet weather than Iodide of Potassium tests when the temperature is low. Vaporization of the Iodide of Starch does not generally take place when the tests are merely damp, but usually when they are moist. Iodized Starch tests do not always bleach during wet weather, either in consequence of the moisture not coming into contact with them, or because, the air being highly ozoniferous, a compensation for any loss that may be sustained occurs by the liberation of fresh Iodine and the formation of more Iodide of Starch. Fogs and mists are occasionally conveyed by currents of air, which are abundantly laden with Ozone or the other purifying agents. In such a case the Iodized Starch tests undergo no blanching. On February 8, 1872, for example, there was a dense sea-fog neutral to red and blue Litmus paper. During its continuance the test papers coloured. The fogs which sometimes visit us in the depth of winter when snow is on the ground often do not blanch coloured tests. The descent of the snow is attended with such an abundant development of air-purifiers that the Iodide of Starch, vaporized with the atmospheric moisture, is soon replaced by fresh decompositions of Iodide of Potassium and formations of Iodide of Starch. If, however, a fog contains but little of the purifying agents of the air, the colour of a test will most probably be removed.

Ozoniferous neutral fogs.

Acid fogs.

Fogs are sometimes very acid from their admixture with Sulphurous Acid. In towns, and even in their suburbs, the presence of this oxide of Sulphur in fogs is often the cause of the removal of colour. This acid, even in an exceedingly dilute form, is a most powerful decolorizing agent. In contradistinction to the fog noted in February 1872 and referred to above, the dense, acid fog which prevailed on November 24th, 1871, may be alluded to. It rapidly reddened blue Litmus paper and decolorized "ozonoscopes." The products of combustion are frequently conveyed long distances by fogs. The acid, odorous fogs, for example, described by Quetelet as visiting

Belgium, have been found by Van Mons to come from Westphalia, where they become mingled with the gases generated in the combustion of peat.

Alkaline fogs.

Fogs have been found to contain large quantities of Ammonia, even as much as 2 grains in 35¼ fluid ounces. The penetrating odour and irritating nature of some fogs have been ascribed to the presence of an excessive amount of this alkali. These ammoniacal fogs may possibly exert a bleaching effect on coloured " ozonoscopes."

THE INFLUENCE OF THE TEMPERATURE OF THE AIR ON "OZONOSCOPES."

A few observers have written down the following formula, and regarded it as a law:—

" As the temperature rises, Ozone diminishes."

Others have noticed that Iodized Starch tests are less coloured, *cæteris paribus*, when the temperature is very low and when it is very high. Chemical action is feeble when the thermometer is extremely depressed. Warmth favours and increases chemical action. When snow and hail showers, which are generally attended by a maximum degree of coloration of tests, are accompanied by a very cold wind that is not usually the bearer of much Ozone, the tinting of the Iodized Starch test is very slight indeed. Mr. Lowe writes,[1] " If the temperature be ranged in 10° series, a temperature between 30° and 40° will give less Ozone than one between 40° and 50°, and this less than one between 50° and 60°." He found that if a night-light were made to burn in a cell below his Ozone box (Plate 10, page 176) so as to warm it, there was an increase in the amount of Ozone over another box that is without a night-light. " As chemical action increases with an increase of heat, it is manifest that a certain quantity of Ozone, passing through the box at a temperature of 60°, would necessarily darken the

Experiment.

[1] *Brit. Assoc. Rep.*, 1862.

paper more than the same amount at a temperature of 40°."

When the temperature of the air is high, much of the Iodine set free by the purifying agents is lost by volatilization. Iodine volatilizes in certain definite proportions according to the temperature as well as the humidity of the air. It proceeds at all ordinary temperatures, being almost infinitesimal below 45°, but tangible in amount at 60° Fahr. Dr. Daubeny has truly said—" The amount of coloration of the Iodized Starch tests is an index, not of the quantity of Iodide of Potassium decomposed, but only of the ratio between the oxidizing action which sets the Iodine free, and the tension of the latter which causes it to evaporate into space."

Volatilization of Iodine.

If, when purifying agents are present in the air, a colourless Iodide of Potassium test and one which has been deeply tinted be placed in a louvre box which is exposed to the rays of the hot sun, the former will colour to a certain extent and then cease to be affected, whilst the latter will fade until it reaches the same degree of coloration. As the temperature falls, both of the tests will increase in tint. The persistence of the colour of the Iodide of Potassium test in cold, dry weather, is doubtless due to the fact that the loss of free Iodine by volatilization is *nil* or at a minimum. When the air is hot and moist this accident is very prone to occur. When a highly ozoniferous wind is blowing, low in temperature and very humid, no volatilization of free Iodine from an Iodide of Potassium coloured test is generally observed, although the paper may even be wet. Immediately, however, an increase in the temperature takes place, volatilization occurs, and the coloured test becomes blanched.

Another experiment.

Let us examine the reports of ozonographers as to the influence of temperature on the indications of tests.

REPORTS OF OZONOGRAPHERS.

Reslhuber gives us the following information respecting the amount of Ozone (?) in 1855 at Kremsmünster :—

Reslhuber at Kremsmünster.

	Day.	No. of Obs.	Night.	No. of Obs.	Mean.
With a *high* * temperature, ...	1·72	(43)	2·94	(41)	2·33
,, *low* † ,, ...	6·16	(25)	6·46	(33)	6·31

* The temperature was considered *high*
When the mean of the days exceeded 66° F., and
,, ,, ,, nights ,, 59°
† The temperature was considered *low* when below 18° F.

MM. Boeckel and Decharmes.

M. Boeckel, M. Decharmes, and others, state that a sudden decrease of temperature favours the formation of Ozone in the air.

Amount of air-purifiers at a station not only determined by local peculiarities, but by the temperature and humidity of its air.

In glancing over the weather registers of different places, the amount of the purifying principles in the air seems not only influenced by local peculiarities, such as the proximity of the sea, of woods, etc., but by conditions of temperature and moisture.

Sometimes one meteorological element seems to regulate their quantity; whilst, at other times, another appears to determine their maximum and minimum periods. If a station has a dry climate, subject to extremes of heat and cold, temperature appears to be the all-powerful agent in influencing the amount which is registered. If, on the other hand, a station be distinguished by a large or excessive amount of humidity, or be much exposed to the equinoctial gales, we notice the influence of the moisture and the force of the wind on the depth of the "ozonometric" tints. An examination, for example, of the following abstract of a weather register,[1] during 1855, shows that the maxima of Ozone (?) development are simultaneous with the minima of the thermometer, and the minima of Ozone (?) with the maxima of the thermometer.

Kremsmünster.

[1] *Untersuchungen über das Atmosphärische Ozone,* by P. A. Reslhuber.

TABLE 38.

ABSTRACT of WEATHER REGISTER in Kremsmünster.

1855.	Mean Amount of Ozone. Schönb. Scale.	Mean Bar. Pressure in Par. Lin.	Mean Temp. R.	Humidity per cent.	Wind.
January	6·37	323'''·64	–3·76	84·87	W.
February	7·84	19 ·79	–2·92	89·21	E. & W.
March	6·21	19 ·70	2·34	83·97	,,
April	6·09	22 ·40	5·43	78·72	,,
May	5·07	21 ·01	9·88	71·38	,,
June	3·18	23 ·02	13·38	71·58	,,
July	2·82	22 ·64	14·34	71·16	W.
August	3·00	23 ·58	14·65	74·06	,,
September	4·37	23 ·80	10·44	82·60	E.
October	4·36	21 ·32	8·61	86·04	E. & W.
November	5·47	22 ·88	1·34	95·72	E.
December	6·33	22 ·97	–5·11	93·73	W.
Means	5·08	322'''·24	5·71	81·92	W.

The comparative dryness of the air during June and July may also be concerned, in conjunction with the heat, in the diminution of the "ozonometric" indications.

Vienna.

In Vienna, during the same year, the direction of the winds would seem solely to have exerted the determining influence, N.W. winds in that city bringing more Ozone (?) than S.E.

The following table, which is an extremely important one, containing as it does a condensed result of the elaborate series of observations made at twenty-four stations in Königsberg, shows—

Conclusions of the Königsberg staff of observers.

1. That the two maxima of "ozonic" reaction occurred when the temperatures were at their minimum, and when the humidity of the air was great, although not excessive.

2. That the minimum of "ozonic" reaction was simultaneous with the maximum temperature, and the lowest relative amount of humidity of the air.

TABLE 39.

WEATHER REGISTER at Königsberg.

YEARS AND MONTHS.		Mean Ozone.	Mean Bar. Pressure.	Mean Temp.	Mean Humidity.
June	1852.	5·5	27″11·57‴	14·23	73·5
July	,,	4·8	28 1·02	15·33	70·2–
August	,,	5·2	28 0·38	14·77	76·2
September	,,	7·1	28 1·10	10·94	77·3
October	,,	8·2	28 0·09	3·83	83·1
November	,,	7·5	27 11·62	1·93	87·1
December	,,	9·2	27 11·50	2·15	89·2+
January	1853.	8·8	28 0·76	– 0·49	88·2+
February	,,	10·9	27 9·39 –	– 2·72	85·9
March	,,	11·2	28 1·64+	– 3·01	82·0
April	,,	10·8	27 11·49	2·88	84·1
May	,,	8·1	28 1·24	9·51	71·4
Mean		8·1	28″ 0·15‴	5·77	80·6

THE INFLUENCE OF THE VELOCITY OF THE AIR ON "OZONOSCOPES."

Assertion of Mr. Smyth.

Mr. Smyth has asserted that "there is not much, if any difference, in the quantity of sensible Ozone in two masses of air of equal volume, moving at different velocities and under different hygrometrical conditions."

My experiments show that the depth of coloration of an "ozonoscope" is influenced to a great extent by the velocity of the air passing over it, and by the amount of moisture contained in the air thus transmitted.

In studying this subject, it is necessary to consider, first, the influence of the velocity of the air on a colourless, and secondly, its influence on a coloured test.

1. *Influence on a Colourless Test.*

The aspirators employed in the following experiments are described on pages 250 and 255.

Each filling of the Mitchell's aspirator is denominated a charge. When the tap was completely open, and the weight of 28 pounds was attached, it consumed on an average fifteen minutes in filling; but when no weight was affixed, thirty minutes were generally occupied.

TABLE 40.

October 30th, 10 A.M.

Bar. 29·580. Steady. Has risen slightly since last night.
Temp. 51·0 dry bulb, 49·0 wet bulb. Overcast.
Wind, S.E. Force, 2·5.
Capacity of Mitchell's aspirator was 44 gallons, or 12,200 cub. inches.
Tests exposed in Smyth's Ozone box.

MITCHELL'S ASPIRATOR.						Tube Aspirator.	Hygrometer.
Iodide of Potassium Test. 15 per cent.							
Charge.	Time.	Tap completely open.		Tap very slightly open.		Average Amount of Air transmitted, 3000 cubic inches, or rather less than one mile, per hour.	
	Min.	28 lb. weight attached. Average velocity 15 miles per hour.	No weight attached. Average velocity $7\frac{1}{2}$ miles per hour.	28 lb. weight attached.	No weight attached.		Dry. Wet.
a.1	13	2 (feeble)	......	...	...	1	51·0—49·0
b.1	$30\frac{1}{2}$	......	3	...	...	2	
c.1	67	......	......	2 (decided) spot	...	$3\frac{1}{2}$	51·5—49·5
d.1	160	......	......	...	3 (decided) spot	4	51·2-49·2 Com. 51·0-49·5 Term.
e.1	15	2	......	...	...	1	51·2—49·2
October 31st, 10 A.M. *Bar.* 29·870. *Temp.* 49·5 dry bulb, 47·0 wet bulb. Overcast. *Wind*, E. Force, 3·0.							
Negretti's Iodide of Potassium and Starch Test.							
f.1	$14\frac{1}{2}$	4	......	...	...	2	49·5—47·0
g.1	32	......	5	...	...	3	49·0—46·2
h.1	$66\frac{1}{2}$	......	......	$4\frac{1}{2}$ (spot.)	...	$5\frac{1}{2}$	49·0—46·5
i.1	145	......	......	...	7 (spot.)	8	49·3—47·4
k.1	15	$3\frac{1}{2}$ or 4	......	...	...	2 (feeble)	49·2—46·2

N.B.—A fresh test was employed for each experiment with both the aspirators.

Remarks on table.

This table unquestionably shows that the depth of colour is less when the weight is attached than when it is unattached. In other words, when the velocity of the air is great there is less colour than when it is little. Why is this? Because when air passes with great rapidity over a test, sufficient time is not allowed the purifying agents contained in the air to act chemically on the test. The same amount of air permitted to pass over an "ozonoscope" at a low rate of velocity, will acquire a deeper tint, in consequence of the greater length of time during which the test is under the influence of the current.

At the termination of each day's experiments a short fifteen minutes' observation was made with Mitchell's aspirator and with the tube aspirator, to ascertain whether as much coloration was produced by the air at their conclusion as at their commencement.

It will be noticed that the colour of the tests exposed in connection with the tube aspirator during the two brief experiments *a* and *f* was less than that of the papers in communication with Mitchell's aspirator, when its tap was completely opened. On the other hand, the colour of these tube aspirator tests was greater than that of the "ozonoscopes" employed during the long exposures, when the tap of the "dry aspirator" was very slightly turned. What is the explanation of this difference? In the brief experiments *a* and *f* with Mitchell's aspirator, 12,200 cubic inches of air passed over the test paper. Only about 650 and 725 cubic inches of air had, however, in 13 minutes and 14½ minutes, respectively, come into contact with the tests in the tube aspirator. The duration of the experiments *b* and *g* being longer, rather more than 1500 cubic inches of air traversed the tube. The small amount of air to which the tests in the tube aspirator were exposed, when compared with the large amount which passed over the tests connected with Mitchell's aspirator, accounts for the greater coloration of the "ozonoscopes" in the latter than in the former case.

Although the velocity of the air in the lengthy experiments was undetermined, it was manifestly greater through Mitchell's aspirator than through the tube aspirator. It will be observed that in the expeiments *c* and *h*, as well as in *d* and *i*, the colour of the tests belonging to Mitchell's aspirator was less than that of the "ozonoscopes" connected with the tube aspirator. In the experiment *d* about 8000 cubic inches, and in that distinguished by the letter *i* about 7250 cubic inches, of air passed over the test in the tube aspirator; whilst 12,200 cubic inches traversed Mitchell's aspirator in each case. How did it happen that in these experiments, *c*, *h*, *d*, and *i*, the colour of the test connected with Mitchell's aspirator was less than the test in the tube aspirator? Because the velocity of the air in Mitchell's aspirator was the greater. Although the quantity of air which passed through the tube aspirator was less than that which came into contact with the test in Mitchell's aspirator, the colour of the paper in the former is deeper, because the velocity of the air influences the tests more than the quantity of the same. This conclusion does not hold good when the differences between the quantity of the air passing over "ozonoscopes" are very great, as, for example, in experiments *a*, *b*, *f*, and *g*. The quantities of air transmitted in the foregoing experiments may be most readily compared by glancing at the following arrangement:—

Amount of air passed over tests in foregoing experiments.

	Aspirator.		
	Mitchell's.	*Tube.*	*Difference.*
Experiments.	Cubic inches.	Cubic inches.	Cubic inches.
a,	12,200	650	11,550
f,		725	11,475
b,	12,200	1525	10,675
g,		1600	10,600
d,	12,200	8000	4,200
i,		7250	4,950

It is thus seen that the velocity of the air which passes over the tests has much to do with their coloration, and especially is this the case if there be but a small

amount of purifying agents contained in it. When, however, these principles are abundant, the difference is not so apparent. It will be shown in the article "On the Duration of Exposure of Tests to the Air," that the tint of an "ozonoscope," as measured by the degrees of the chromatic scales which are employed, does not increase in arithmetical progression with the amount of ozoniferous air passing over it. It requires much more Ozone to raise a test from No. 5 to 6 of the scale than from 2 to 3; and very much more to elevate it from 9 to 10 than from 5 to 6. When tests advance beyond the feebler, and especially when they acquire the deeper shades, they appear, provided there is no increase in the amount of Ozone or its allied purifying principles in the air, for this reason sluggish in their behaviour. In order to raise them ½ or 1 degree of the scale, it becomes necessary to pass a very large amount of air over them. When a test has reached one of these decided or deeper tints, it appears to be not only less sensitive to successive charges of air passed over it, but less affected by variations in the velocity of the current, so long as that current is feeble.

Torpid condition of tests.

Mr Smyth's observations.

The results obtained by Mr. Smyth, which have led him into error, are, on examination, explicable by a consideration of the latter fact.

TABLE 41.

DR. ANDREWS' form of ASPIRATOR of a capacity of 110 Gallons.

Date.	Ozone.			Wind.		Velocity in miles per hour.		Mean Temperature.	Relative Humidity, saturation = 100	Remarks.
	Test in Ozone Box.	Test in Clarke's Ozone Cage.	Time exposed.	Force.	Direction.	Air in Aspirator.	Wind.			
1866.			hours.							
Jan. 4	7	7	23	4	S.	·16	...	40	87	
,, 11	7	9	23	0	N.W.	·16	...	31	95	
,, 12	7	8	23	4	S.W.	·16	7	38	94	
,, 19	7	7	22	4	W.	·16	11	46	88	
,, 25	7	7	16	3	S.W.	·24	3·8	46	88	
,, 27	7	8	16	4	S.	·24	4·6	43	88	
Feb. 8	7	7	23	4	S.	·16	...	41	92	
,, 22	6	8	1·5	4	W.	2·58	...	38	77	
,, 23	7	8	3	4	S.W.	1·29	...	39	86	
1867.										
Mar. 12	7	4	23	4	N.E.	·16	...	35	83	

Remarks on Smyth's observations.

When these observations were made the air-purifiers were evidently abundant, as evinced by the depth of the coloration of the tests. We see that on February 23, although the velocity of the air employed was much greater than on the days in January when No. 7 was invariably obtained, the same colour was registered. There was, in truth, no sensible difference in the depth of tint of the tests exposed to the two currents of different velocities. When the velocity of the air was further increased, in fact was doubled, on February 22, we have one degree less, namely No. 6. If Mr. Smyth had made comparative experiments when the amount of air-purifiers was less, or had employed less sensitive tests, and if he had exposed some of them to currents of air of higher degrees of velocity, such as we have in the winds, he would have obtained more striking results which would have led him to a different conclusion. When we re-

member that "the lightest breath of air" of which we are conscious travels at 1·4 miles per hour, it is evident that Mr. Smyth employed currents of extreme slowness, which manifested but slight effects on tests in an inactive condition.

2. *Influence on a Coloured Test.*

(*a*) Potassium Iodide test.

Cold and moist air will not remove the colour from an Iodide of Potassium test which has become tinted during an exposure to the air. When the air is saturated with moisture, volatilization of the free Iodine occurs, and will take place to a greater extent if the velocity of the current of air passing over the test be great than if it be little.

TABLE 42.

November 24, 6·20 P.M., 1871.
Coloured Iodide of Potassium Test, No. 5.
Bar. 29·810 ; *Temp.* dry bulb, 38°, wet bulb, 37·5 ; *Wind*, S.W. ; Dense Fog.

Mitchell's Aspirator.

Time.	Tap fully turned. 28 lbs. weight attached.	Tap fully turned. No weight attached.	Hygrometer.		Remarks.
Min.			D.B.	W.B.	
(*a*) 16	No. 7. White spot in centre of test, very decided.		37·7	37·7	The increase in colour of the tests where volatilization did not occur was doubtless due to the moisture, for coloured tests are always darker when damp than when dry.
(*b*) 34	....	No. 6. Indistinct spot in centre where there has been a slight degree of blanching. The removal of colour is very much less than in experiment (*a*).	37·5	37·5	
(*c*) 15	No. 6	....	39·0	38·0	Fog has almost gone. Little mist only.

The foregoing experiments were conducted during a fog produced by the condensation of the moisture of a

S.W. current of air (temperature 38°) in its passage over a soil possessing a temperature of 35·5°.

Remarks on table.

The table shows (*a*) that when air is saturated with moisture there is a larger amount of volatilization of free Iodine when the velocity of the current of air is great than when it is little; and (*b*) that when cold air is not saturated with moisture a sensible amount of volatilization does not occur during brief exposures (*vide* experiment *c*). If the air be *warm* and moist, a perceptible degree of volatilization of the free Iodine will happen when the amount of moisture in the air is short of saturation. Why is this? Partly because volatilization of Iodine is greater at high than at low temperatures, and partly because the air contains more moisture at a high temperature than at a low one, although the differences between the dry and wet bulb thermometers may be the same in each case. For example—

Dry Bulb.	Wet Bulb.	Vapour in Cubic Foot of Air.
38·0	38·0 = sat.	2·7 grains.
38·0	37·0	2·4 ,,
68·0	68·0 = sat.	7·5 grains.
68·0	67·0	7·1 ,,

In summer especially, when the air is often warm and very moist, although not saturated with humidity, we accordingly find that volatilization of the free Iodine is greater when a coloured Iodide of Potassium test is exposed to a rapid than to a slow current of air.

It is probable that when the velocity of the current of air passing over a test is extremely rapid, the force of impact also begins to operate.

(*b*) Iodized Starch test.

As regards the coloured Iodized Starch tests and the influence on them of air of different velocities, Scoutetten gives us information which coincides with the result of our experiments and confirms their accuracy. He writes:

Scoutetten's experiment.

—"If an ozonoscope be exposed to a current of ozonised air of a velocity of 100 metres per minute, and a second test be submitted to a current of 200 metres during the

same length of time, it very often happens that the test with which the greater quantity of air has come into contact will show the least amount of coloration, because the rapidity of the current has favoured the vaporization of the Iodide of Starch."

Velocity of air to which tests should be exposed.

Test papers should not, in my opinion, be exposed to a current of air of greater velocity than about a mile per hour. In the case of the extremely sensitive Iodide of Potassium test this precaution is indispensable, in order to guard against loss of free Iodine by evaporation. In the case of the Iodized Litmus tests, where such care is not absolutely necessary, the transmission of a more rapid current is useless. When currents of air are passed over test papers with great rapidity, sufficient time is not allowed for the fixation of much of the purifying agents which accordingly escape.

THE DURATION OF THE EXPOSURE OF TESTS TO THE AIR.

Frequent changes in the weather.

There is one very obvious objection to long exposures, arising from the frequent changes to which the weather is liable, especially in insular climates. We have already seen that the colour of the tests is very often removed by the accession of certain atmospheric states.

The Königsberg observers found great discrepancies in their results arising from this cause. In their report they insert the following table, which well illustrates the fallacy arising from long exposures.

TABLE 43.

Date.	8 A.M.	12 Noon.	2 P.M.	4 P.M.	8 P.M.	Date.	8 A.M.	12 Noon.	2 P.M.	4 P.M.	8 P.M.
May 2 . . *a*	.	.	.	0	2	May 10 . . *a*	1	.	4	.	0
b	.	.	.	.	2	*b*	1	.	.	.	0
,, 3 . . *a*	1	.	.	3	0	*c*	1	.	.	.	4
b	1	.	.	.	2	,, 11 . . *a*	1	.	0	.	4
,, 4 . . *a*	5	.	.	3	0	*b*	1	.	.	.	0
b	5	.	.	.	2	*c*	5	.	.	.	5
,, 5 . . *a*	2	.	.	3	0	,, 12 . . *a*	8	.	.	.	0
b	2	.	.	.	2	*b*	8	.	.	.	0
,, 6 . . *a*	6	.	.	5	0	*c*	8	.	.	.	6
b	6	.	.	.	1	,, 13 . . *a*	0	.	.	.	0
,, 7 . . *a*	6	.	5	.	7	*b*	0	.	.	.	0
b	6	.	.	.	8	*c*	7	.	.	.	5
,, 8 . . *a*	7	4	.	4	0	,, 14 . . *a*	0	.	.	.	1
b	7	.	.	.	4	*b*	0	.	.	.	1
,, 9 . . *a*	0	0	.	.	0	*c*	6	.	.	.	3
b	0	.	.	.	0	,, 15 . . *a*	0	.	.	.	0
c	2	.	.	.	1	*b*	0	.	.	.	0
						c	6	.	.	.	4

The observations (*b*) extended from 8 A.M. to 8 P.M.
,, ,, (*a*) ,, ,, 8 A.M. to 4 P.M. on five days, to 2 P.M. on three days, to noon on one day, and to noon and 4 P.M. on another day.

Two hours' observations.

Reslhuber of Kremsmünster, finding that his Ozone tests exhibited, after a two hours' exposure, as much coloration as if submitted to the action of the air for a whole day, provided that the temperature and hygrometric condition remained the same, adopted the shorter period.

When observations are made in an atmosphere loaded with an abundance of air-purifiers, as Ozone, etc., such as envelopes small islands or stations surrounded by a quantity of luxuriant vegetation, short observations are demanded, otherwise a removal of colour, from an excess of Ozone, may render the results unreliable. Large amounts of Ozone are moreover not indicated, in an atmosphere so powerfully impregnated, by the deepest tints of "ozonoscopes." In conducting observations at the Lighthouse

Observations every six hours.

near Whitby, the Rev. F. Stow was compelled to substitute six-hour for twelve-hour observations, as he discovered that when tests were exposed for the longer period, the maximum was exceeded on five days out of six. Below is an example of the mode in which he endeavoured to represent the maxima.

Mode of representing maxima.

October 1870.

Date.	Tint.	Date.	Tint.	Date.	Tint.	Date.	Tint.	Date.	Tint.	Date.	Tint.
1...	8 —	6...	8 —	11...	7 —	16...	12 —	21...	7 —	26...	0
2...	9 —	7...	6 —	12...	10 —	17...	8 —	22...	9 —	27...	11
3...	10 —	8...	12 —	13...	11 —	18...	6 —	23...	10 —	28...	9
4...	10 —	9...	11 —	14...	5 —	19...	10 —	24...	8 —	29...	12
5...	9 —	10...	10 —	15...	7 —	20...	8 —	25...	6 —	30...	6
										31...	10

10 = Maximum of Schönbein's Ozone scale attained in six hours.
11 = Maximum attained in three hours.
12 = Maximum attained in one and a half hour.

Ozonoscopes often rapidly colour up to a certain point, and there remain for many hours without any visible increase in tint, although fresh tests exposed during this period become coloured; for example—

Experiment.

A colourless test (1)	exposed at	10 A.M.	had acquired	No. 6	tint at	10 P.M.	
„ „ (2)	„	10 A.M.	„	No. 5	„	2 P.M.	of the same day.
„ „ (3)	„	2 P.M.	„	No. 4	„	6 P.M.	
„ „ (4)	„	6 P.M.	„	No. 5	„	10 P.M.	
				14			

In this experiment the test exposed during twelve hours yielded No. 6 of the scale, whilst the total number of degrees furnished by the three successive observations, each lasting four hours only, was fourteen, although carried on during the same period of time. Here, then, we have a difference of eight degrees.

The want of any definite rate of progression in the deepness of the tints assumed by Iodized Starch tests, in proportion to the number of hours during which they have been exposed, has tended to shake the confidence of observers in this test considered as a measure of quantity.

The following abstract of a table published by Dr. Daubeny represents indications afforded by Schönbein's test papers exposed in the open air during four, eight, and twelve consecutive hours.

Daubeny's experiments.

TABLE 44.

Date.	Hours. 4	8	12
July 16 . .	2	2	2
17 . .	2	3	3
18 . .	1	1	2
19 . .	3	3	3
20 . .	2	2	2
21 . .	1	1	4
22 . .	0	1	1
23 . .	0	0	0
24 . .	1	3	4
25 .	1	2	5
26 . .	1	3	6

Inactive condition of tests.

Mr. Buchan and his coadjutors seem, in their experiments [1] with aspirators, to have been considerably puzzled by this refusal of the tests to increase in tint with length of exposure. On June 11th and 23d, Schönbein's test paper, exposed to currents of air from Mitchell's aspirator, afforded the subjoined degrees of coloration.

On June 11th, with		On June 23d, with	
1 charge, the tint was	4	1 charge the tint was scarcely perceptible.	
2 charges „ „	4	1 „ „ „	1
3 „ „ „	4	2 charges „ „	3
4 „ „ „	4	3 „ „ „	4
		4 „ „ „	4

A tint as deep was obtained in the experiments on June 11 after drawing $4\frac{1}{2}$ cubic feet of air over the tests, as when four times that amount was employed. "A limit seemed to be quickly reached, which was not passed by bringing the tests in contact with twice, thrice, or four times the quantity of air."

The following experiments, made by me with Mitchell's and with the tube aspirators, show the difficulty

[1] "Report on Ozone Observations:" *Journ. Scottish Meteor. Socy.*, January and April 1872.

which is sometimes experienced in raising the colour of the test even one degree of the scale.

Experiments in proof.

TABLE 45.

November 9, 1871.

Bar. 29·486 ; *Temp.* 39·5 dry bulb, 37·5 wet bulb ; *Wind*, W. ; Force, 2·5. Cloudless.

All of the following observations were sixteen minutes in duration, with the exception of the 13th which continued thirty-five minutes.

N.B.—Each filling of the aspirator is denominated a "Charge."

Charge.	Mitchell's Aspirator. Tests. Iodide of Potassium.	Mitchell's Aspirator. Tests. Iod. Starch. Negretti's.	Tube Asp. Iodide of Potassium.	Barometer and Hygrometer, Cloud, etc.	D.	W.	
	Weight of 28	lbs attached.					
1	1	½	½	29·486	39·5	37·5	Cloudless.
2	1¼	1	¾				
3	1¾	2	1				
4	2	2½	1½		41·0	38·0	
5	2½	2¾	2				
6	2¾	3	2¼				
7	2¾	3	2½		42·0	38·5	
8	2¾	3½	2½				
9	3	4	2½				
10	3	4	2½				
11	3	4	2¾		42·0	38·0	
12	3¼	4	2¾				
	No weight	attached.					
13	3½	4¼	3·0	29·456	41·0	38·0	
	Weight	attached.		Wind W., Force 2·5, Cloud 7.			
14	1*						

* This last charge was passed over a fresh test to ascertain whether as much of the colouring principles were contained in the air at the termination as at the commencement of the experiments.

These experiments show that, although the tests arrive at a degree of coloration at which they appear to remain stationary, it is possible to increase slowly the tint, unless the air-purifiers disappear, by perseveringly exposing them to fresh quantities of air.

How is it that the tests do not exhibit a record of the amount of air-purifiers which may have passed over them by successive charges in constantly accumulated depths of tint? The salt present on the surface of the fresh Iodide of Potassium test is at first decomposed. The Iodine set free, as it increases in quantity, of course deepens the tint. A point is at length reached when the Iodide of Potassium present on the surface and in the most superficial layer of the test paper is all decomposed. In order that the test shall continue to increase in tint, it is necessary for the deeper layers of Iodide of Potassium to be acted upon. If the amount of Ozone in the air be small, it will be found difficult, even by passing repeatedly fresh quantities of air over the tests, to raise the tint ¼ or ½ a degree after this stage has been reached. If either a fall of snow or a strong sea-breeze should supervene, the large amount of Ozone thereby brought into contact with the tests will rapidly deepen the colour several degrees of the scale.

Its cause.

It has been already pointed out that a far larger amount of air-purifiers is necessary in order that a test may be raised from No. 6 to 7 than from No. 1 to 2 ; and from 9 to 10 than from 6 to 7. It must not be thought, then, that a test of tint No. 10 indicates the presence of ten times as much of the air-purifiers as one of No. 1 tint. The maximum tint should, if such a proportionate progressive increase is expected, be more correctly represented by some multiple of 10, such as 30, 50, 70, or perhaps 100.

When the amount of purifying agents in the air is exceedingly small, and the air is passed over the test with rapidity, it sometimes requires five or six charges of Mitchell's aspirator in order to attain No. 1 of the scale. A very small percentage of these principles acting on the test in such a case, only faint traces of their presence can be left when the air contains only a small quantity of them.

Frequent changes in the weather.

The possibility of the occurrence of sudden changes in the weather, during the exposure of tests readily affected by the same, renders it needful to expose such tests for brief periods. We often find that if the weather becomes rapidly warm and damp the Iodide of Potassium tests, instead of increasing in tint with additional charges of the aspirator, will diminish in colour in consequence of the volatilization of more Iodine than is set free. This accident is still more likely to occur if the velocity of the air and the length of exposure be great.

A decision as to duration of exposure should be arrived at.

The duration of the exposure of an "ozonoscope" is then an important matter to be settled. If a five minutes' observation be adopted, as recommended by Mr. Smyth, tests of extreme sensibility must be used, or a large amount of air must be transmitted over the test at a great velocity, in order to obtain an amount of colour which can be conveniently estimated. Tests of extreme sensibility will not keep unless they have been prepared and are preserved with the greatest care. The objection to the employment of a current of great velocity has already been adverted to (pages 280-288).

By adopting short periods of observation for the Iodide of Potassium tests, any error from volatilization of the free Iodine, in consequence of an excess of moisture in the air, is, if gauzes and a current of about a mile per hour are employed, reduced to a minimum.

Recommendation.

In estimating the amount of purifying principles contained in the air, a one-hour observation should be made twice a day with a 10 or 15 per cent Iodide of Potassium test. In the estimation of Ozone, the Iodized and non-Iodized red Litmus tests should be exposed without intermission, being changed every twelve or twenty-four hours. The brief observations with the Iodide of Potassium tests may be most conveniently managed by conducting them during the breakfast and supper hours.

THE INFLUENCE OF LIGHT ON "OZONOSCOPES."

Liberation of Iodine from Iodide of Potassium.

The light of the sun, especially its direct rays, has been said to liberate Iodine from Iodide of Potassium. When this salt is associated with Starch, the blue Iodide of Starch has been declared to be bleached by the light.

Decolorization of Iodized Starch tests.

Dr. Daubeny of Oxford, having noted a diminution in the tints of his coloured Iodized Starch tests when subjected to the light, enclosed them in open blackened tubes whilst under the influence of the air.

The following abstract of a table published by him[1] exhibits a considerable difference in the indications of the tests :—

TABLE 46.

EXPERIMENTS during the DAY in the SHADE.

Date.	Tube blackened.			Tube not blackened.		
	Hours.			Hours.		
	4	8	12	4	8	12
July 14	0	0	0	4	4	5
" 15	0	0	2	0	3	3
" 16	0	0	0	0	2	2
" 17	0	2	2	2	2	3
Aug. 1	1	1	1	3	3	4
" 2	0	0	2	1	2	3
" 3	0	1	3	0	2	4
" 4	0	2	3	2	3	5

Dr. Rankin of Auchengray observed that the colour of Iodized Starch tests was less deep when they were exposed to than when shaded from the light.

Tests stated by some to be uninfluenced by light.

Dr. Mitchell sealed some "ozonoscopes" in a glass tube and submitted them for months to the influence of an African sun without the occurrence of any change. A negative result also followed an exposure of a solution of Starch and Iodide of Potassium to the light. As some

[1] *Journal of Chemical Society*, vol. v., Ser. 2, January 1867.

difference of opinion would thus seem to exist regarding the effect of light on "ozonoscopes," let us study its action on both colourless and coloured Iodide of Potassium and Iodized Starch tests.

Experiments.

The following experiments were performed by me in October and November 1871 :—

October 3, 11 A.M., wind E.N.E., no sunshine.

A colourless Iodide of Potassium (10 per cent) test
and a coloured „ „ „ test (No. 7)
were exposed to diffused daylight for four hours, between slips of crown glass firmly pressed together by means of elastic bands.

At 3 P.M. the colourless Iodide of Potassium test was No. 3,
and the coloured „ „ „ „ „ 8,

A coloration of the colourless and a slight increase of the tint of the coloured test was observed a few days after under the influence of sunshine.

On October 8, noon—wind N.W., showers accompanied with occasional glimpses of sunshine—a colourless Iodide of Potassium test was placed in a test tube which was securely corked and exposed to the light. A coloured Iodide of Potassium test, No. $8\frac{1}{2}$, was similarly treated. The tests were exposed until 6 P.M. on October 9—a sunshiny day with a North wind—when it was found that the colourless Iodide of Potassium test in tube was No. 1,
and the coloured „ „ „ „ „ $7\frac{1}{2}$.

The heat of the sun had evidently produced volatilization of the free Iodine, which could not so readily take place in the first experiment where the tests were firmly compressed between glasses.

With blue, yellow, and red rays.

Thinking that a knowledge of the effects of the three primitive-coloured rays of light, of which the prismatic spectrum is composed, might elucidate this subject, and be in other respects of interest, I exposed tests between slips of colourless, blue, yellow, and red glass, with the following results :—

TABLE 47.

Glass.	Colourless Iodide of Potassium Tests. 10 per cent.	Coloured Iodide of Potassium Tests. 10 per cent. No. 7.	Colourless Iodized Starch Tests. (Negretti.)	Coloured Iodized Starch Tests (Negretti), No. 5.	
				1st exp.	2d exp.
Crown . . .	2	8	3	$1\frac{1}{4}$	3
Blue	$1\frac{1}{2}$	7	2	$1\frac{1}{4}$	$3\frac{3}{4}$
Yellow . .	1	6	1	5	5
Red	$\frac{1}{2}$	$5\frac{1}{4}$	0	$2\frac{1}{2}$	4

Results.

These experiments show—

1. That white light tints both kinds of colourless tests most powerfully;

2. That white light most strongly intensifies the colour of a coloured Iodide of Potassium, and diminishes that of a coloured Iodized Starch test;

3. That the blue or chemical rays exert an action precisely similar to that of white light, although less in degree.

4. That the yellow or light rays colour the colourless tests less deeply than the blue rays, but more deeply than the red rays. They, moreover, have little or no effect on the coloured tests;

5. That the red or heating rays have the least effect on the colourless tests; whilst they produce a very decided decolorization of coloured Iodide of Potassium, and a sensible removal of tint from coloured Iodized Starch tests.

The loss of colour experienced by the coloured Iodide of Potassium tests, under the influence of the red or heating rays, is doubtless due to the volatilization of the free Iodine; whilst the considerable decolorization of the Iodide of Starch, when submitted to the action of the blue rays and of white light, is the result of some chemical change which it undergoes.

Explanation of Drs. Rankin and Mitchell's results.

The tests of Dr. Rankin, made of a mixture of Starch and Iodide of Potassium, were evidently bleached to some extent by the light; whilst the "ozonoscopes" employed by Dr. Mitchell lacked sufficient sensibility to exhibit any action under the influence of the sun. If the latter papers had been of greater strength, the heat to which they were also subjected was sufficient to have volatilized any vestige of Iodine set free.

Impure Iodide of Potassium is more susceptible than pure.

Light influences Iodide of Potassium, containing as impurities Carbonate of Potash and traces of free Iodine, more readily than the *pure* salt, as M. Payen has proved. Stoppered red or black glass bottles should be employed for the preservation of sensitive tests, even if the Iodide of Potassium, of which they are composed, is pure. If these tests are inadvertently exposed to diffused daylight in a colourless, a blue, or a yellow bottle, they will assume a straw tint.

Tests should be always in the dark.

Test papers during their exposure to the air should be in darkness. Mr. Smyth disregarded this important point in his experiments, for the Ozone box which bears his name admits an abundance.

CHROMATIC SCALES

are not employed in "ozonometry" by MM. Bérigny, Salleron, and Houzeau. They simply count the number of days on which tests undergo coloration. Every method based on a comparison of tints must be to a certain extent imperfect; yet it is one of greater precision than any other of that class which is characterized by simplicity in management. Many opinions prevail as to the number of shades of colour into which a chromatic scale should be divided. Dr. Allnatt has suggested that the "ozonometric" scale should consist of eight parts, so that the individual tints may not be so indeterminate as to render comparison difficult. Mr. Smyth thinks that scales do not register high enough. Whatever decision may ultimately be arrived at as to the number of shades

Difference of opinion as to the number of degrees.

of colour which—by their union—should form a scale, the following rules must be remembered:—

Rules.

1. The chromatic scales employed by all observers should be divided into the same number of parts, each tint being easily distinguishable from its neighbour, and identical in depth of coloration with those possessing corresponding numbers in all other scales of the same kind.

2. Each gradation of colour should be of a hue exactly similar to that assumed by the tests during their exposure to the air.

In the case of colourless tests which display, after having been submitted to the action of the air, various shades of one colour—as, for example, the Iodide of Potassium test—both of these rules may be observed, and the amount of purifying principles may thus be estimated with the closest approach to accuracy.

Undesirable to adhere to the rule No. 2 in case of Iodized Litmus test.

When, however, a test possessing a definite colour gradually loses it during an exposure and slowly becomes of a tint entirely different—as, for example, the Iodized Litmus test—the rule No. 2 cannot be advantageously adhered to. Delicate shades of difference in tint cannot in such a case be estimated without difficulty, as they are extremely liable to be confounded with each other. The degrees of colour must be widely distinct, in order that mistakes may be avoided. Although the Iodized Litmus tests are rendered blue, in the absence of all decided change of tint of the non-Iodized Litmus paper, by *Ozone solely*, it will be found that this blue colour is often modified by some of the constituents of the air, and grey or slate tints are thus produced. *True* ozonometry, or the measurement of the amount of Ozone in the atmosphere to the exclusion of the other air-purifiers, cannot, in the present state of our knowledge, be conducted with any great refinement. A general idea may be formed of the variations in its amount. An advance may be made, beyond the rough and ready way of noting simply the num-

ber of days on which any blue coloration occurs, by employing a chromatic scale.

In estimating the amount of Ozone, the attached scale of three degrees is recommended; whilst in the estimation of the quantity of the air-purifiers, the appended scale of ten is employed by me.

For estimation of Ozone.

No. 1.—Ozonometer or Chromatic Scale = 3 Degrees.
For Estimation of Ozone.
o, Iodized vinous-red Litmus test before exposure.

For estimation of air-purifiers.

No. 2.—Chromatic Scale = 10 Degrees.

For Estimation of Air-Purifiers { Ozone. Peroxide of Hydrogen. Nitrous Acid.

The colours assumed by the Iodized Litmus tests often appear widely different from those of the scale, for the reasons above alluded to. We must take note more of the degree to which the vinous red colour has been replaced by the blue, than of the correspondence of the tints of the exposed tests with those of the scale. The degree of the scale to which the exposed Iodized Litmus test bears the closest resemblance must be registered.

A counterpart on the scale No. 2 will readily be found for each tint displayed by the Iodide of Potassium test after an exposure.

Concluding Suggestions.

The prevention of disease being *the* great end and aim of the medical art, how important is it that *savants* should fully investigate the amount and functions in the air of these active agents!

Munificence of the Marquis of Tweeddale.

There seems to be at present an earnest desire on the part of the Council of the Scottish Meteorological Society, which has been encouraged by the princely liberality of the Marquis of Tweeddale, to make a vigorous effort in this direction.

A *thoroughly accurate* estimation of the amount of Ozone present in the pure air of different climates, and during the various atmospheric conditions of each climate, should first be obtained. Being possessed of this information, we shall be in a position to attempt an elucidation of the following and many other questions, which are of immense interest and importance to the human race:—

Subjects for investigation.

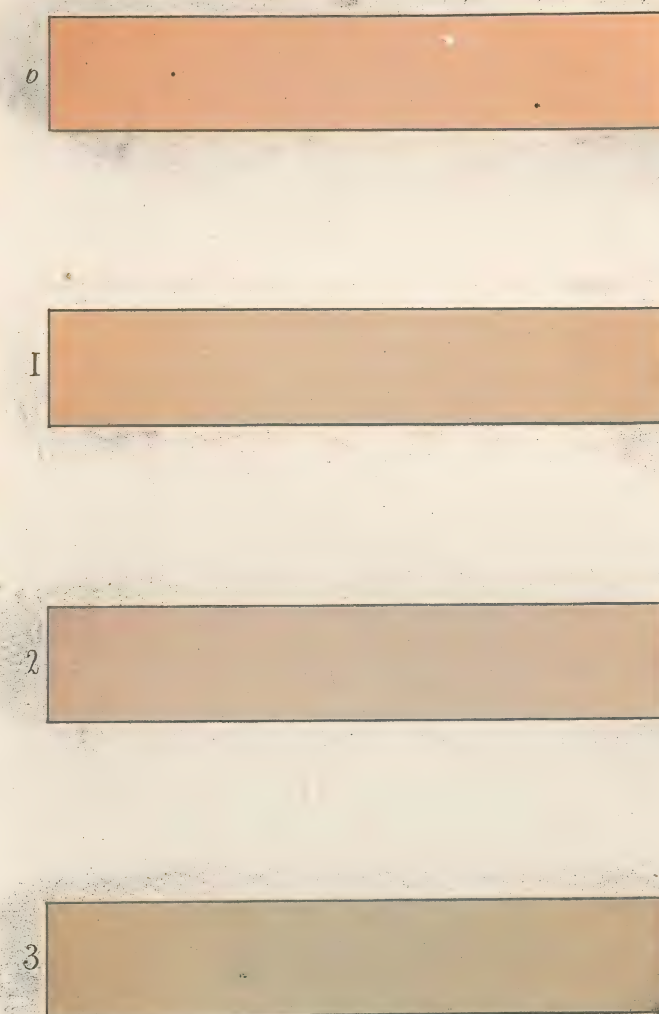
1. What are *all* the sources of atmospheric Ozone?
2. How is it formed, and in what circumstances does it arise?
3. What is its precise action on animals and plants?
4. Has an excess or deficiency of Ozone any effect on the public health?
5. If so, what is the nature of that influence?
6. What is the effect of the presence of epidemics on its amount, as calculated by the improved ozonometric method?
7. Does Ozone oxidize one only, or all of the different kinds of organic matter found in the air?

Whilst echoing the last cry of the illustrious Goethe —"More light! more light!"—let us gird up our loins and endeavour without further delay to penetrate into this unknown world, remembering the ancient motto of all students of nature and her laws—

"βιος βραχυς ἥ τεχνη μακρη."

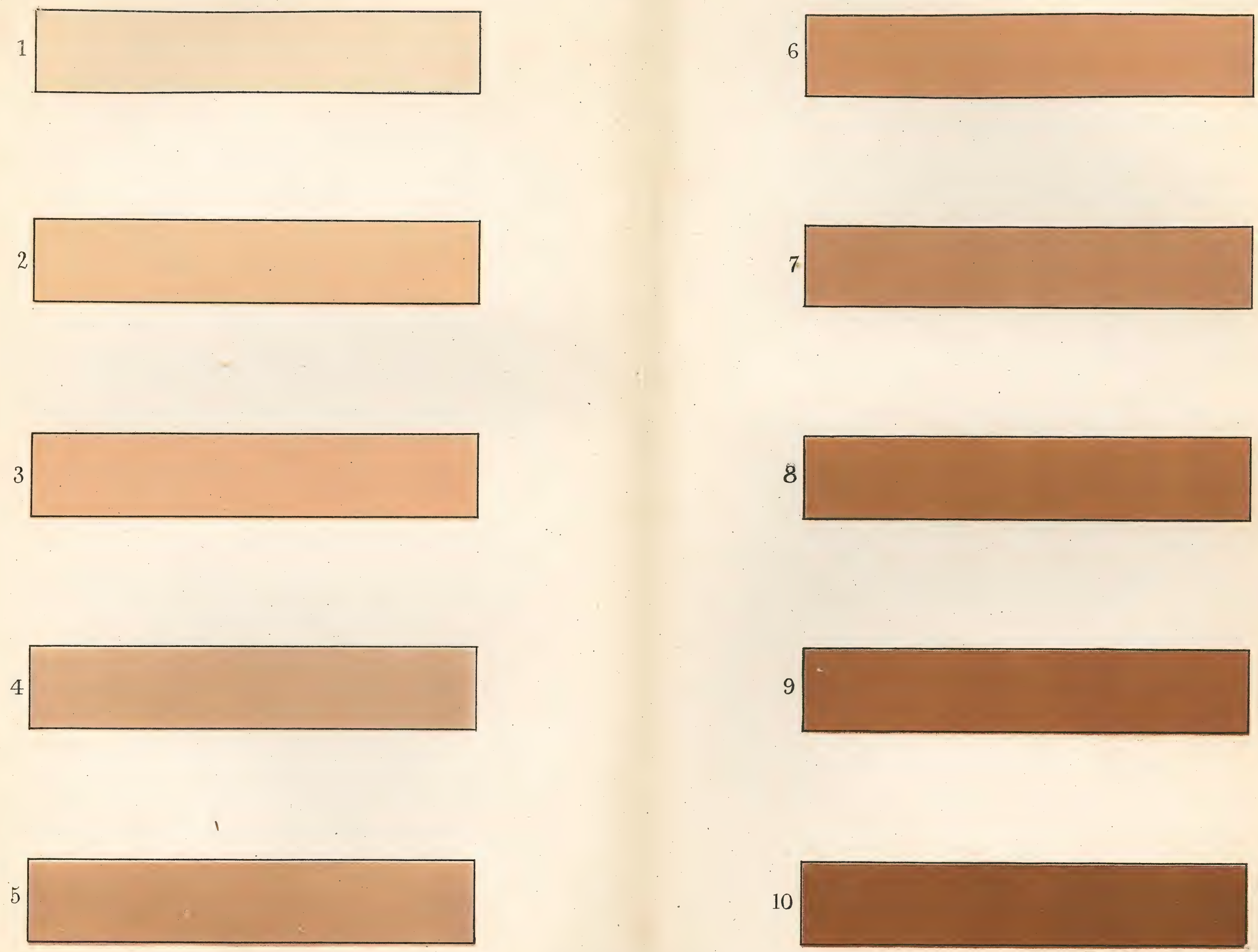
OZONOMETER
CHROMATIC SCALE.

N°. I.



CHROMATIC SCALE

No. 2.



OZONE REGISTER,

AT ....

Month of .... *18*........ *Periods of Observation* .... *a.m.* *and* .... *p.m.* .... *ft. above Mean Sea Level*

Date	AIR PURIFIERS	OZONE	TEMPERATURE DB	TEMPERATURE WB	Bar	Wind	Rain	CLOUDS Kind	CLOUDS Amount 0–10	*Remarks as to weather, &c.*
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
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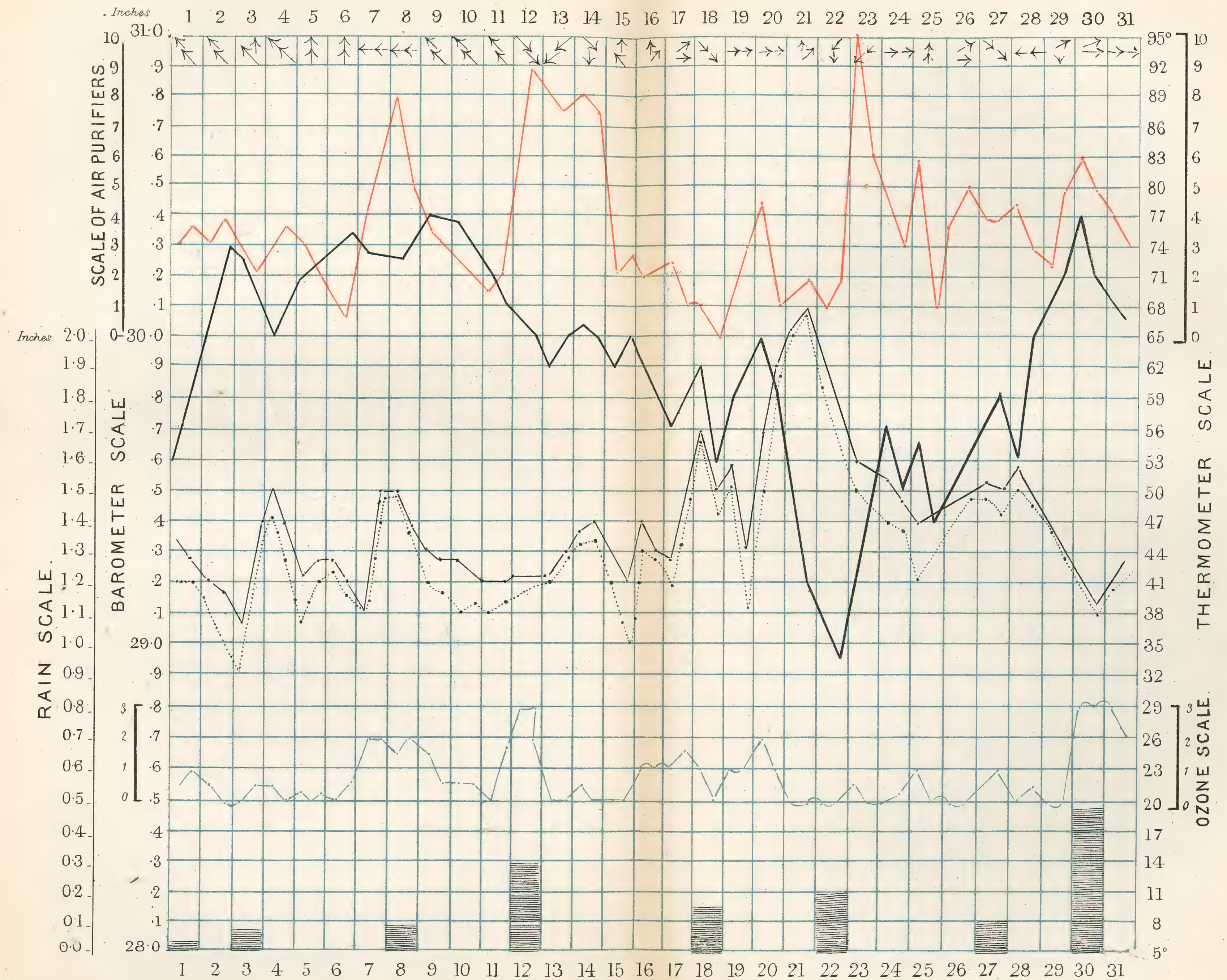
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
Means										

DIAGRAM OF OZONE, AIR PURIFIERS, BAROMETER, THERMOMETER, RAIN & WIND.

at ________________________ *during* ________________ *18* ______



MODIFICATION

OF

SYMONS' METEOROLOGICAL DIAGRAM.

The vertical blue lines represent midnight, and the space between each 24 hours; therefore, in entering an observation, taken for instance at 9 A.M. on the 1st, the mark should be about one-third the breadth of a column to the right of the blue boundary line; 11 P.M. on the 6th would be almost on the vertical line between the figures 6 and 7.

1. *Ozone.* A blue line may be employed to distinguish the fluctuations in the quantity of this body, whilst the amount of the
2. *Air Purifiers* is conveniently indicated by a red pencil, or *vice versâ.*
3. *Thermometer.* Two observations on temperature should be made in the 24 hours. It will be seen that each horizontal line indicates a rise of 3 degrees.
4. *Hygrometer.* The temperature of the wet bulb thermometer may be dotted in below the morning and evening dry bulb observations.
5. *Wind* may be advantageously marked in the uppermost line of squares, the top of each square being taken as N, the right hand as E, and so on; arrows should be drawn crossing the centres of the squares in the direction of the wind. If two observations daily are entered, the later should be placed below the earlier.
6. *Barometer* should be read once, or if convenient twice, daily. The observations may be entered either corrected or otherwise; a dot should be made at the point represented by its height and the time of observation, and the dots should be joined by a thick black line.
7. *Rain* is best shown by filling up as many squares as there have fallen tenths of an inch.

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